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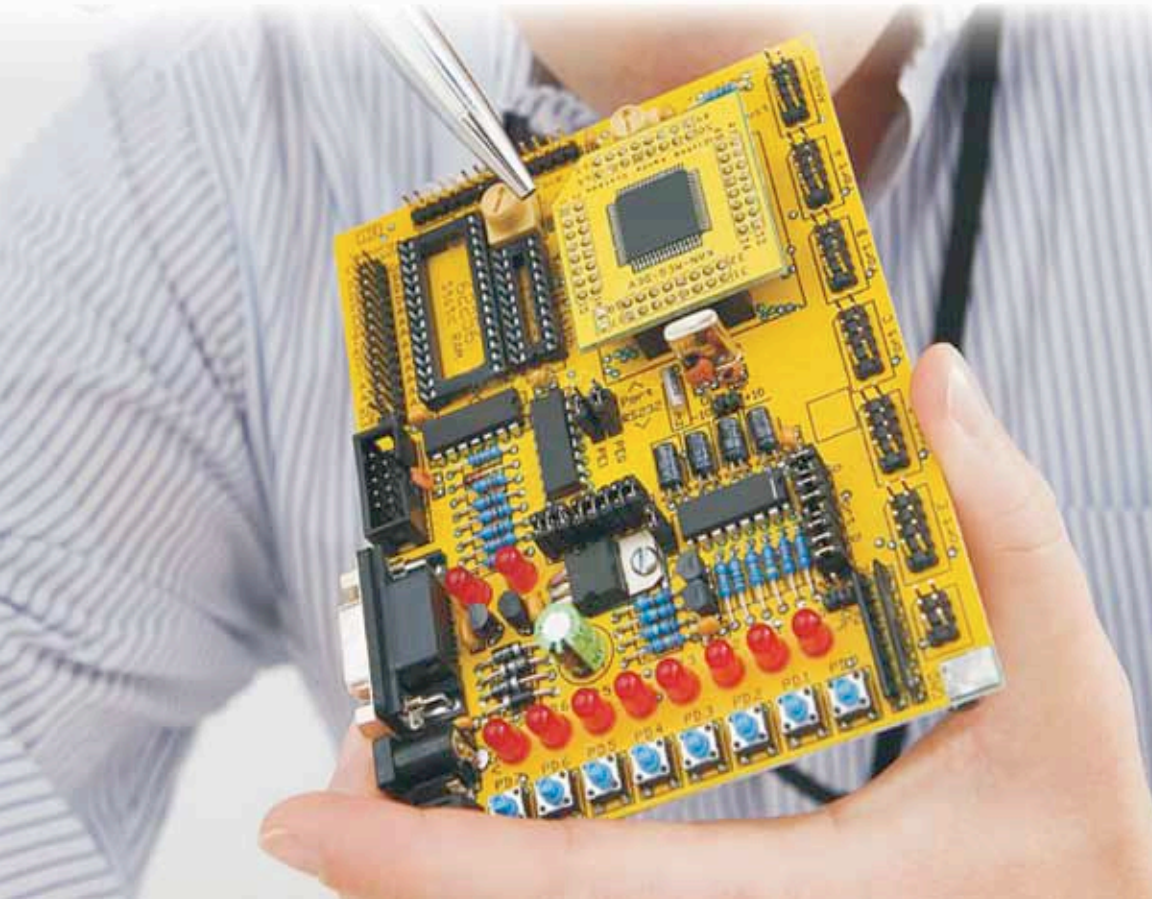

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CHIP-TALK
Electronics Experimenters' Project-book

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CHIP-TALK
Electronics Experimenters' Project-book

Compiled by

Gp Capt (Retd) K C Bhasin

EFY Enterprises Pvt Ltd

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Foreword

Persistent demand from a section of our readers, which include science and engineering students and budding hobbyists who desire to step into this fascinating world of electronics, has led us to bring out this unique publication titled "Chip-talk." All semiconductor devices from a small IC through Application-Specific Integrated Circuit (ASIC) to systems-on-a-chip (SOC) are nicknamed 'Chip.'

Part I of the book is specially devoted to those readers who have little or no previous exposure to electronics fundamentals, wiring or assembly of circuits on a breadboard or stripboard and their testing. Part II contains selected projects along with their underlying principles, proper description, parts list etc. Even experienced professionals would stand to gain something from it. Some important features of this book are:

- It starts from scratch. It does not assume that every reader is familiar with the basic tools, symbols and other materials used for assembling a prototype of a circuit using breadboarding techniques. It explains all aspects of assembly techniques using 60 odd figures and tables.
- It familiarizes you with an interpretation of the marking on basic passive and active components to determine their value, tolerance and rating etc. It also shows how various components, as used in the practical circuits covered in the book, look like and what are the good circuit assembling practices and the precautions to be exercised.
- Before proceeding with any project/circuit, the features of components used therein, including their truth tables, where relevant, are properly explained.

Part II comprising four separate sections offers 40 interesting projects along with 100 odd figures and truth tables. The projects have been picked up from nearly a thousand circuits that have appeared in EFY magazine over the past decade or so. Additional material has been added to aid understanding of the basic chips (ICs) used in these circuits. All the circuits have been retested at EFY-Lab and optimised for their performance. The projects covered in sections 1 through 4 are based on the following themes:

- Section 1: Melody generator projects based on UM66TXXX IC
- Section 2: TTL and CMOS logic based circuits
- Section 3: Timer and counter based circuits
- Section 4: A collection of interesting miscellaneous projects

The circuits in sections 1 through 3 can be easily assembled using breadboard or stripboard and tested by a reader having just the basic skill, tools and test equipment. The stabilized power supply circuit described in part I can be used for powering most of these projects. For testing of logic circuits, a versatile probe design has also been included in part I along with the PCB layout Some of the circuits included in Section 4 may require slightly higher level of skill and use of a proper printed circuit board for their assembly.

Attempts are being made to supply the project kits/essential parts (as per the parts list) through our associates, Kits'n'Spares. Basic tools mentioned in Part I of the book would also be made available through Kits'n'Spares. The availability and prices of kits may be checked from them before placing orders. Any suggestions for improvement of the book may or kits/tools please be forwarded to Kits'n'Spares at the following address:

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D-88/3, Basement, Okhla Industrial Area, Phase 1, New Delhi 110020,
Phone: 011-26371661, E-mail: info@kitsnspares.com

Chief Editor
Electronics For You

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PART I
Basic Electronics

Circuit symbols and conventions

Please familiarize yourself with various circuit symbols as shown below (in Figs. 1 through 11), which are extensively used while drawing the schematic diagrams of electronic circuits.

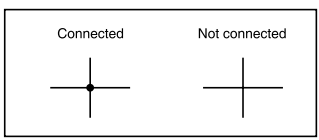


Fig. 1: Wire connection

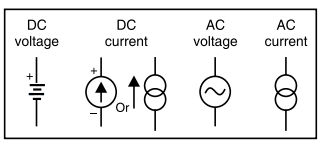


Fig. 2: Power supply sources

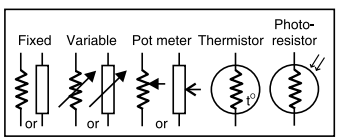


Fig. 3: Resistors

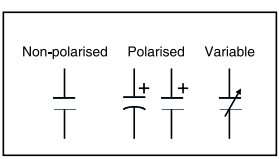


Fig. 4: Capacitors

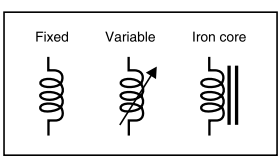


Fig. 5: Inductors

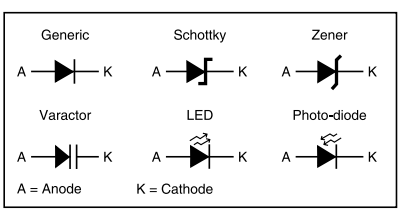


Fig. 6: Diodes

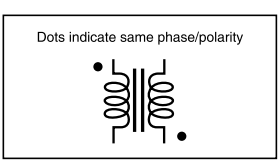


Fig. 7: Transformer

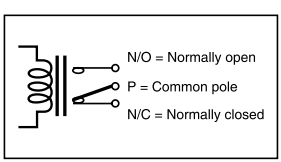


Fig. 8: Relay

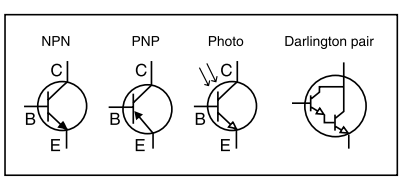


Fig. 9: Transistors`

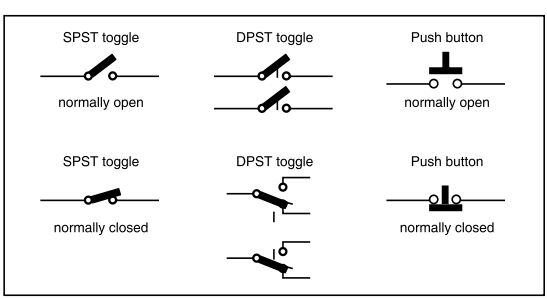


Fig. 10: Switches (SPST=Single Pole Single Throw; DPST=Double Pole Single Throw)

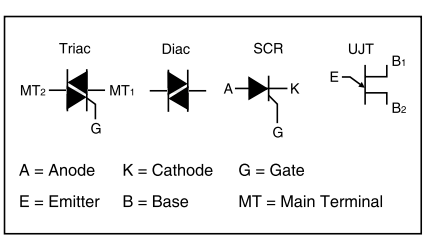


Fig. 11: Thyristors

Safety first

It is wise to take all necessary precautions to avoid risk to life or injuries, or damage equipment. Follow these tips:

- **Follow all codes for handling electrical devices.** Unplug the AC cords before opening the case of an electrical or electronic device. Don't work on mains power equipment while alone. Always have another person nearby who can shut off the power or call for help in case of an emergency.
- **Workbench**. Always keep your soldering iron on its stand and unplug your iron every time you leave the room. Use only those outlets that have proper fuses or circuit breakers, and don't plug too many devices into one socket.
- **Use common sense**. Don't work on equipment when you are sick or tired, or under the influence of drugs of any kind.

Basic tools and test equipment

Your skill level is more important than tools and test equipment. The basic tools for electronics project construction are relatively inexpensive, and all of them are likely to be available through your local electronics parts dealers. The basic tools required for electronics projects are of two types: hand tools and soldering tools.

Fig. 12: Toolkit

1. Hand tools. The hand tools are really simple at 'entry level.' These may comprise:

Long nose pliers: These will come handy for holding or bending the leads of components and holding nuts while you tighten bolts.

Cutting pliers: What you need are 'flush cutting' pliers rather than the traditional 'dikes' or 'diagonal cutting pliers.' As their name suggests, side cutters have blades placed at one side so that they can be used to easily and neatly crop the ends of component leads after they have been soldered to a piece of stripboard or a printed circuit board (PCB).

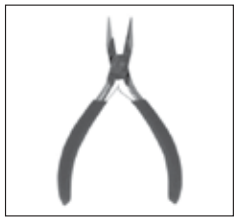


Fig. 13: Long nose pliers

Fig. 14: Flush cutting pliers

Electrician's pliers: A pair of economical lap-jointed electrician's pliers with PVC handles will provide safety while working with AC mains.

Fig. 15: Electrician's pliers

Wire strippers: You will most likely be using thin gauge of wire (single core or stranded) when connecting off-board components to the stripboard or CB (circuit board), or when constructing a prototype circuit on breadboard. Wire strippers like the one shown can be easily adjusted to make stripping insulation off these types of wire simple.

Fig. 16: Wire stripper

Screwdrivers: You will need two large screwdrivers, one with a straight tip for slotted screws, the other with a Phillips head; and a set of miniature drivers (flathead and Philips head). The mini screwdrivers (often called "jeweler's drivers") can be bought as separate sets for straight and Philips heads, or as a combination set. In addition, a mains tester-cum-screwdriver will prove useful.

Fig. 17: Screw drivers

Hexagonal head L-key set: In electronic equipment, many a times one comes across grub screws having hex-

agonal socket heads. The L-key set comes handy for opening/tightening these grub screws.

Fig. 18: Hexagonal-head L-key set

Magnifiers: A magnifying lens is sometimes required to see the small markings on components and examine circuit board traces and solder connections. If you can, you should solder under magnification using a magnifying work lamp, but you can start with a hand-held magnifier.

Fig. 19: Magnifier

Tweezers: Tweezers are very useful for holding screws and seating or aligning them into their threaded holes, and for holding thin wires while soldering, or picking up and holding small components.

Fig. 20: Tweezers

Clip leads: These are wires with alligator clips on the ends for making temporary connections. These can also serve as heatsinks while soldering heat-sensitive components.

In addition, hobby knife, available from stationery and hobby shops, with a razor-sharp blade, for stripping wires and trimming things could prove valuable.

Fig. 21: Alligator clip

Apart from the basic essential tools described above, certain additional tools and test equipment described below may prove useful for an electronics hobbyist/technician.

Fig. 22: Files

Files: Various types of files such as rasp, round, triangular and flat files prove useful while working with chassis or other enclosures for smoothing edges after any mechanical work.

Small portable electric drill: An electric drill capable of holding drill bits with maximum diameter of 6mm will meet most of your needs. Those who can not afford an electric drill may buy a hand drill. A simple way of drilling holes (1 mm to 2mm) in PCB is by making use of a hand-operated ratchet drill, which is quite cheap. It is spring-loaded and drills a hole when it is pressed down from handle.

Fig. 23: Small portable electric drill

Track cutter: A 3mm drill bit can be used instead; in fact the tool is usually just a 3mm drill bit with a proper handle fitted.

Fig. 24: Track cutter

2. Multimeter. For checking voltages, resistances, continuity and current, a digital multimeter with an 'audible continuity feature' is great, but you can get by with an inexpensive analogue multimeter (Volt-Ohm-Milliameter).

Fig. 25: Digital multimeters

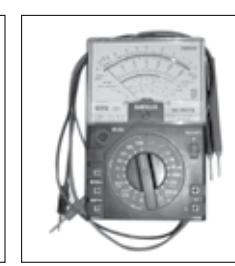


Fig. 26: Analogue multimeter

3. Logic probe. For checking logic levels as well as activity on digital lines/pins, one needs to use a logic probe. It is provided with two croc-

Fig. 27: Logic probe

odile/alligator terminals for connection to logic voltages from the equipment under test. (Clip with red sleeve for positive and clip with black sleeve for negative/ground terminals.)

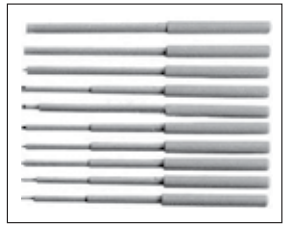


Fig. 28: Trimming tool set

4. Trimming tool set. A set of trimming tools made from tough durable ABS, designed for the alignment of trimmers, presets, cores, etc, with hex, square or slotted heads is useful where use of screwdriver is not advisable because of hand capacitance effect.

Fig. 29: Soldering iron

Fig. 30: Soldering iron stand with sponge

Soldering/de-soldering

For soldering and de-soldering, you will need the following additional tools:

Fig. 31: De-soldering pump

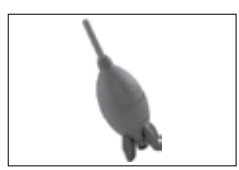


Fig. 32: De-soldering bulb with nozzle

De-soldering pump/Solder sucker: It is a tool for removing solder when de-soldering a joint to correct a mistake or replace a component. It is a spring-loaded suction pump with teflon nozzle. A cheaper suction pump comprises a nozzle directly plugged into a rubberised bulb.

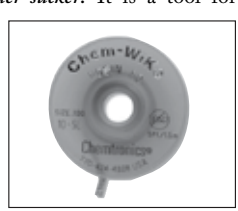


Fig. 33: De-soldering Wick

De-soldering wick: It is a copper braid woven using fine copper wire and is impregnated with flux. It comes in rolls of one to one-and-a-half meter length. About a cm or so of the wick is placed over the soldered joint to be de-soldered and the hot solder-iron tip is pressed over it. As the solder melts, it gets trapped into the braid's mesh.

Fig. 34: Rosin-core solder reel

Rosin-core solder: The best size for electronics work is 20 to 22swg (standard wire gauge). The solder wire contains flux in the hollow core of the solder allowing it to be applied automatically when you heat the solder.

Soldering tips

Soldering is the most basic and critical skill in electronics. A poor soldering job results into hard-to-trace circuit faults. Hence it is important to do the job right the first time. Follow the tips given below religiously; you should have no problem mastering the art.

- **Use the proper soldering iron for the job in hand.** For most of the work use a pencil iron of 25 to 40 watts with a 3mm (1/8-inch) chisel tip. A larger iron can lift the copper tracks off the circuit board, melt insulation from wires and damage components.
- **Use small-diameter resin-core solder.** The solder for these projects should be a 60:40 tin-lead alloy about 20 to 22 swg in dia.
- **Keep the tip of the iron clean.** Rub the tip frequently over a damp sponge to remove excess solder and resin.
- **Make good mechanical connections before applying solder.** Twist multi-strand wires tightly, since loose strands may result into shorts. Wrap wire around posts with the long-nose pliers. Push wires through the printed circuit board and bend them slightly on the bottom side (track side). When you are ready to solder, take your hands off the work. All the wires to be soldered should stay in place.
- **Heat the joint and not the solder.** Use very little solder over the iron (tin only the tip), and then place the tip on the joint. When the joint begins to heat, touch the solder to the joint and not to the iron. The solder should melt and then automatically flow over the joint. When the joint is uniformly

covered with solder, remove the solder followed by the soldering iron. Let the joint cool for a few seconds before you pull the wires or leads of components to check.

- **Inspect the joint.** The joint should be covered with a smooth and shiny coat of solder. There shouldn't be any untinned wires or hapzard buildup of excess resin. Do look for any fine strands of wire or bridges of solder between the joint, which could result into undesired shorts. These can usually be removed with de-soldering wick or soldering iron.

Safety precautions to prevent electric shock

You must observe the following safety precautions when working on an electrical equipment:

- Never work alone. Another person may save your life if you receive an electric shock.
- Work on energised circuits ONLY WHEN ABSOLUTELY NECESSARY. Power should be tagged out (disconnected), using approved tagout procedures, at the nearest source of electricity.
- Stand on an approved insulating material, such as a rubber mat.
- Discharge power capacitors before working on de-energised equipment. Remember, a capacitor is an electrical power storage device.
- When you must work on an energised circuit, wear rubber gloves and cover as much of your body as practical with an insulating material (such as shirt sleeves). This is especially important when you are working in a warm space where sweating may occur.
- De-energise equipment prior to hooking up or removing test equipment.
- Work with only one hand inside the equipment. Keep the other hand clear of all obstacles that may provide a path, such as a ground, for current to flow.
- Wear safety goggles. Sparks could damage your eyes, as could the cooling liquids in some components such as transformers in case they overheat and explode.
- Keep a cool head and think about the possible consequences before performing any action. Carelessness is the cause of most accidents. Remember the best technician is NOT necessarily the fastest one but the one who will be on the job tomorrow as well.

Ohm's law

Relationship between voltage (V) across a resistor (load), current (I) through the resistor and resulting power (P) consumed by the resistor can be expressed in various ways or formulae as shown in Fig. 35.

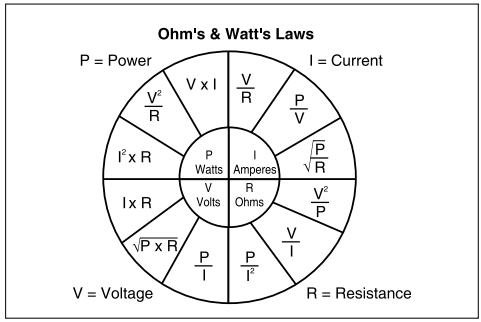


Fig. 35: Chart showing relationship amongst current, voltage, power and resistance

As an experiment you can set up a circuit by connecting resistors in series with a battery (cells), measure the voltage across the resistors with a voltmeter, measure the current in the circuit by placing an ammeter in series with the resistors and battery. If you know the voltages and current in the circuit you can use Ohm's law to calculate the resistance and power. With the resistor out of the circuit you can measure its resistance directly with an ohmmeter. The multimeters today can measure ohms, volts and amperes—all with one piece of test equipment.

Resistor values are expressed in units known as Ohms, symbol for which is Ω.

Fixed and variable resistors

There are two kinds of resistors, Fixed and Variable. The fixed resistor will have one value which will never change (other than through temperature, age, etc). A

Typical Resistor	Type	Symbol
	Fixed Carbon	
	Fixed Wirewound (Tapped)	
	Adjustable Wirewound	
	Potentiometer	
	Rheostat	

Fig. 36 (a): Various types of fixed and variable resistors

tapped resistor has several fixed taps and makes more than one resistance value available. The sliding contact resistor, shown below it has an adjustable collar that can be moved to tap off any resistance within the range of the resistor.

There are two types of variable resistors, one called a Potentiometer and the other a Rheostat. An example of the potentiometer is the volume control on your radio, and an example of the rheostat is the dimmer control for the dash lights in an automobile. There is a slight difference between them. Rheostats usually have two connections, one fixed and the other moveable. Any variable resistor can probably be called a rheostat. The potentiometer always has three connections, two fixed and one moveable. Generally, the rheostat has a limited range of values and a high current-handling capability. The potentiometer has a wide range of values, but it usually has a limited current-handling capability. Potentiometers are always connected as voltage dividers.

Resistor colour code and conventions

In the standard colour code system, four bands are painted on the resistor, while on some other systems 5 or 6 bands are painted as shown in Fig. 36 (b).

While these codes are most often associated with resistors, they can also apply to capacitors and other components.

The standard colour coding method for resistors uses a different colour to represent each number 0 to 9: black, brown, red, orange, yellow, green, blue, purple, gray, white. On a 4-band resistor, the first two bands represent the first two significant digits. On a 5- and 6-band resistor, the first three bands represent the significant digits. The next band represents the multiplier or 'decade'.

As in the above 4-band example, the first two bands are red and purple, representing 2 and 7. The third band is orange, representing 3, which mean 10^3 or 1000. This gives a value of 27×1000, or 27000 ohms. The gold and silver decade bands divide by a power of 10, allowing for values below 10 ohms.

The 5- and 6-band resistors work exactly the same way as the 4-band resistors. They just add one more significant digit. The band after the decade is the tolerance. This tells how accurate is the resistance compared to its specification. The 5-band resistor has a gold tolerance, or 5%, which indicates that the true value of the resistor could be 5% more or less than 27000 ohms, i.e., anywhere between 25650 and 28350 ohms.

The last band on a 6-band resistor is the temperature coefficient of the resistor, measured in PPM/°C or parts per million per degree Centigrade. Brown (100 PPM/°C) is the most popular, and will work for most reasonable temperature conditions. The others are specially designed for temperature critical applications.

1. Naming convention: To simplify the writing of large resistor values, the abbreviations K and M are used for one thousand and one million. To keep the convention standard, R is used to represent a decimal. Because of problems in seeing the decimal point in some printed texts, the 3 letters, K or M or R, are used in place of the decimal point. Thus, a 2,700-ohm resistor is written as 2K7 and a 6.8-ohm resistor is written as 6R8.

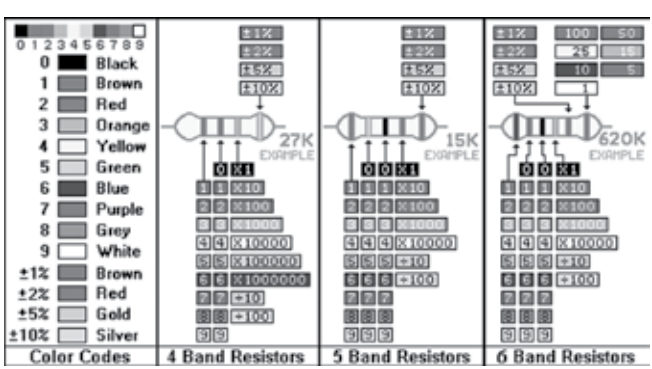


Fig. 36 (b): Resistor colour code and conventions

2. The E12 range: This is a range of resistors that are known as 'preferred values'. In the E12 range there are 12 'preferred' or 'basic' resistor values, and all the others are simply decades of these values:

1.0, 1.2, 1.5, 1.8, 2.2, 2.7, 3.3, 3.9, 4.7, 5.6, 6.8 and 8.2

3. The E24 range: The E24 range of preferred values includes all the E12 values, plus a further 12 to enable the selection of more precise resistances. In the E24 range the preferred values are:

1.0, 1.1, 1.2, 1.3, 1.5, 1.6, 1.8, 2.0,

2.2, 2.4, 2.7, 3.0, 3.3, 3.6, 3.9, 4.3, 4.7, 5.1, 5.6, 6.2, 6.8, 7.5, 8.2 and 9.1

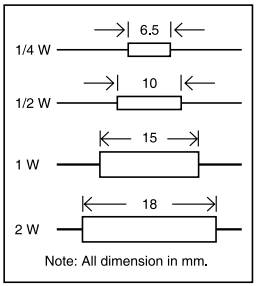


Fig. 37: Carbon resistor size and wattage relationship

4. Simplifying the colour code: There are numerous memory-aid acronyms that may help you remember the code in its proper order. Each word (or bold character in uppercase) in the following acronyms represents the first letter of the colours (black, brown, red, orange, yellow, green, violet, grey and white respectively). If you match it up with the colour code, you will not forget the code. Pick up any of these acronyms.

B. B. ROY Great Britain Very Good Wife

Bad **B**eer **R**ots **O**ur **Y**oung **G**uts, **B**ut **V**odka **G**oes **W**ell

Billy **B**rown **R**evives **O**n **Y**our **G**in, **B**ut **V**alues **G**ood **W**hisky

Better **B**e **R**eady, **O**r **Y**our **G**reat **B**ig **V**enture **G**oes **W**est

5. Resistor wattage: The power that a resistor can safely dissipate (without burning) depends on its size. Typical sizes of carbon resistors for ¼ W, ½ W, 1 W and 2 W are 6.5 mm (0.25 inch), 10 mm (0.4 inch), 15 mm (0.6 inch) and 18 mm (0.7 inch) respectively, as shown in Fig. 37.

Capacitors

Capacitors are common components of electronic circuits, used almost as frequently as resistors. The basic difference between the two is that capacitor resistance (called reactance) depends on frequency (when used in AC circuit) and its capacitance. The reactance is denoted by Xc, and can be calculated using the formula:

$$X_C = \frac{1}{2\pi fC}$$

where f represents the frequency in hertz (Hz) and C represents the capacitance in farads (F).

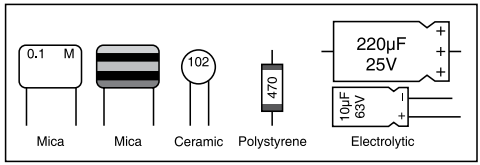


Fig. 38: Assorted capacitors (Mica, ceramic, polystyrene and electrolytic)

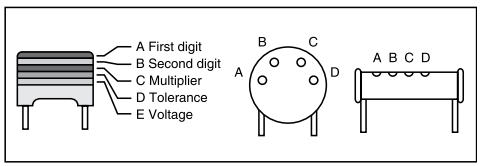


Fig. 39: Some colour coding schemes for fixed capacitors

COLOR	DIGIT	MULTIPLE	TOLERANCE	VOLTAGE
Black	0	x 1 pF	±20%	
Brown	1	x 10 pF	±1%	
Red	2	x 100 pF	±2%	2.50V
Orange	3	x 1 nF	±2.5%	
Yellow	4	x 10 nF		400V
Green	5	x 100 nF	±5%	
Blue	6	x 1 µF		
Violent	7	x 10 µF		
Grey	8	x 100 µF		
White	9	x 1000 µF	±10%	

Fig. 40: Colour marking/coding scheme for capacitors (refer Fig. 39 for colour bands)

For example, 5nF (n = nano =10^{-9}) capacitor's reactance at f=125kHz equals:

$$X_C = \frac{1}{2\times 3.14\times 125000\times 5\times 10^{-9}} = 225\Omega$$

Colour coding and marking schemes for fixed capacitors: A Farad may be denoted in various ways as: 1F=10^6µF =10^9nF=10^{12}pF, where µ denotes micro, n denotes nano and p denotes pico or micro-micro. There are no international agreements in place to standardise

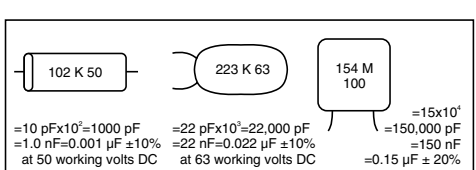


Fig. 41: Plastic film capacitors showing capacitance value, tolerance and working voltage

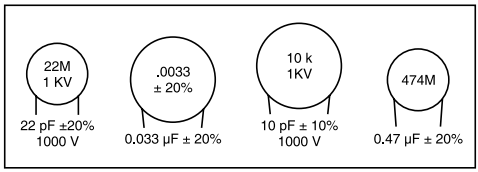


Fig. 42: Ceramic disk capacitors

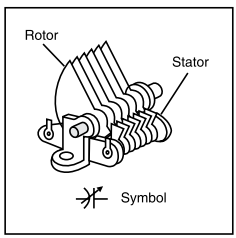


Fig. 43: Variable capacitor (air dielectric)

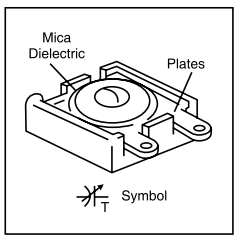


Fig. 44: Trimmer capacitor and symbols

capacitor identification. Most plastic film types have values which are printed over the capacitor. If the symbol used is µ, the value is in microfarads and if the symbol used is n, the value is in nanofarads. The working voltage is easily identified. Tolerances are identified by the upper case letters as follows: M=20%, K=10%, J=5%, H = 2.5% and F = ± 1pF.

Some examples of decoding the values of plastic and ceramic disk capacitors are shown in Figs. 41 and 42. A capacitor coded 474K63 means that its value is 47×10^4 pF or 470000 pF or 0.47 microfarads. K indicates 10% tolerance. The next digits—(63) signifies its working voltage.

TABLE 1

IEC letter and digit code for R & C values

Resistance values		Coded marking	Capacitance values		Coded marking
0.15	Ω	R15	0.15	pF	p15
1.5	Ω	1R5	1.5	pF	1p5
15.0	Ω	15R	15.0	pF	15p
1.5	kΩ	1K5	1.5	nF	In5
150	kΩ	150K	150	nF	150n
1.5	MΩ	1M5	1.5	µF	1µ5
15	MΩ	15M	15	µF	15µ
1.5	GΩ	1G5	1.5	mF	1m5
1.5	TΩ	1T5	15	mF	15m

TABLE 2

Capacitance Conversion

0.000001 µF	=	0.001nF	=	1 pF
0.00001 µF	=	0.01 nF	=	10 pF
0.0001 µF	=	0.1 nF	=	100 pF
0.001 µF	=	1 nF	=	1000 pF
0.01 µF	=	10 nF	=	10000 nF
0.1 µF	=	100 nF	=	100000 nF
1 µF	=	1000 nF	=	1000000 nF
10 µF	=	10000 nF	=	10000000 nF
100 µF	=	100000 nF	=	100000000 nF

IEC letter and digit code for R & C values

For resistors, R, K, M, G and T are used as multipliers for 1, 10^3, 10^6, 10^9 and 10^{12}, respectively, of resistance values expressed in ohms. For capacitors, p, n, µ, m and F are used as multipliers for 10^{-12}, 10^{-9}, 10^{-6}, 10^{-3} and 1, respectively, of the capacitance values expressed in farads.

A conversion table for capacitance values in micro Farad (µF) to equivalent values in nano Farad (nF) and pico Farad (pF) is given here for ready reference (Table 2). Note the relationship amongst the Farad (F) and its various sub-units: $F=10^6$ µF$=10^9$nF$=10^{12}$pF

Inductors (coils)

Inductors are used for the storage of magnetic energy. Magnetic energy is stored as long as current keeps flowing through the inductor. In a perfect inductor, the current of a sine wave lags the voltage by 90°. An inductor is a coil of wire, with a core of air (no core), iron or ferrite material. Its electrical property of opposing any change in current flowing through it is termed inductance, and the unit for this is Henry, represented by symbol H. 1H is very large inductance, hence mH and µH are generally used; 1H =1000mH and 1mH

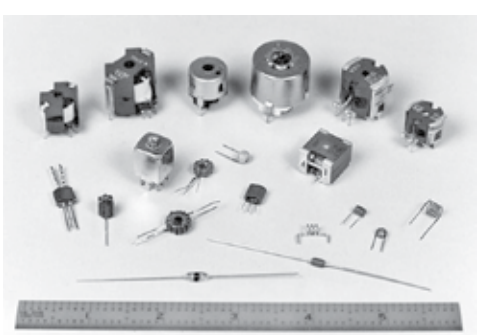


Fig. 44: An assortment of inductors

=1000μH. Iron and ferrite cores increase the inductance of coils.

Inductors are normally used in tuned circuits and filters, and also to block AC signals (choke is also an inductor). The inductors pass DC easily but impede AC signals. This property of inductors is the opposite to that of capacitors.

Inductive reactance: X_L, the impedance of an inductor to an AC signal, is given by the equation:

$$X_L = 2\pi fL$$

where X_L=inductive reactance (ohm), f=frequency (Hz) and L=inductance (henry).

The type of wire used for its construction does not affect the inductance of a coil. Q of the coil (ratio of reactance to resistance) is governed by the resistance of the wire. Therefore coils wound with silver or gold wire have the highest Q for a given design.

Circuit assembly

Electronic circuits in various magazines/books are published in the form of schematic diagrams, which show the interconnections of various components of the circuit. They include the power supply/batteries and output load, which may be just an LED, a speaker or any other appliance. To make the circuit perform its expected task, the circuit components have to be physically interconnected. Primarily, three types of circuit boards, as described below, are used for performing interconnections.

1. Breadboard: A breadboard is used for making solderless temporary connections using leads, which are pushed into the holes in the board to make connections. This is basically a way of wiring a circuit temporarily, for testing purposes or to try out an idea. Since no soldering is done, all the components can be reused afterwards. It is easy to change connections and replace components. Fig. 46 shows the external appearance of a breadboard. It has two rows of supply/ground channels on the top and bottom, separated by two 5-hole vertical channel rows.

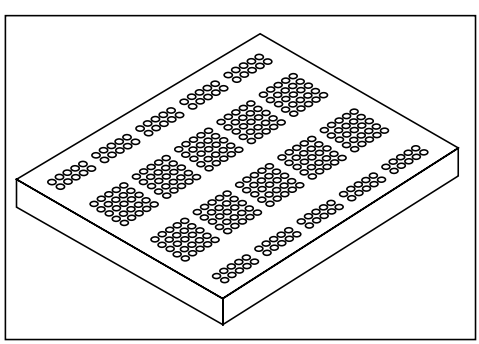


Fig. 46: External appearance of a breadboard

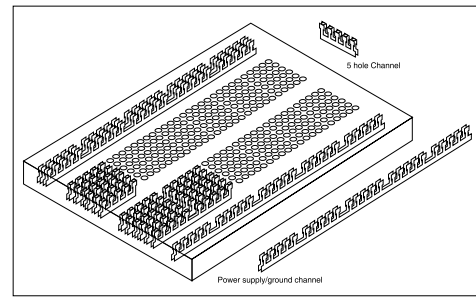


Fig. 47: Conductor channels embedded inside a breadboard

The conductor channels embedded under the holes are shown in Fig. 47. If you rip open the breadboard from the bottom, you can easily see these conducting channels. All adjacent holes are separated by 2.54 mm (0.1 inch), enabling direct insertion of most ICs that have identical pin-to-pin spacing. Normally, two sections of the breadboard, as shown in Fig. 46, are integrated into a single unit and are sold as a single breadboard.

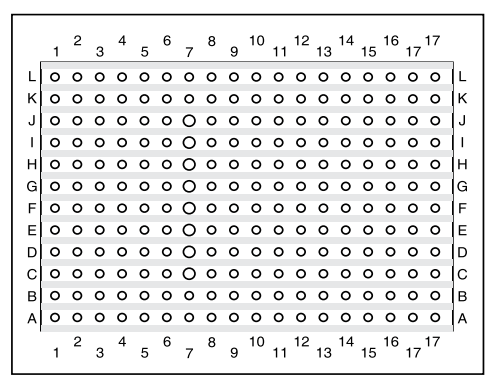


Fig. 48 (A): Bare stripboard

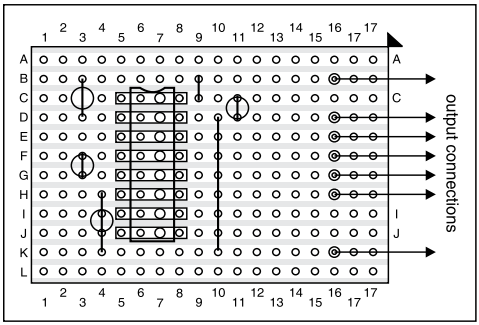


Fig. 48 (B): Assembled stripboard

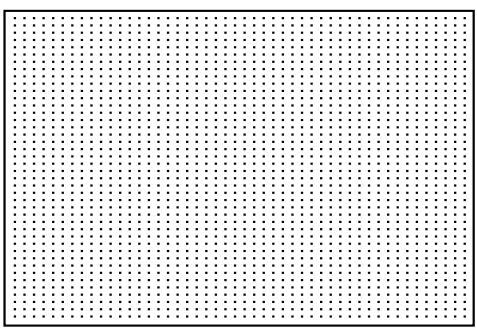


Fig. 49: Stripboard planning sheet

2. Stripboard (Fig. 48): A stripboard is somewhat similar to a breadboard. It has a regular matrix of holes that are 2.54 mm (0.1 inch) apart, for component leads, which are arranged as parallel copper tracks. The difference is that the components are to be soldered to the tracks, to use the stripboard to make the circuits you want. Unlike the breadboard, a stripboard can be cut and drilled to meet the size requirements of your prototype.

Always plan the layout of your stripboard on paper before you attempt any soldering! A grid such as the Stripboard Layout Planning Sheet shown in Fig. 49 may be downloaded from: http://www.eleinmec.com/downloads/sbps.zip.

3. Printed circuit board: Printed circuit boards have copper tracks connecting the holes where the components are placed. These are designed specially for each circuit and make construction much easier. This method is not recommended for beginners unless the PCB is provided to you.

Illustrations of some commonly used components

1. Tactile switch

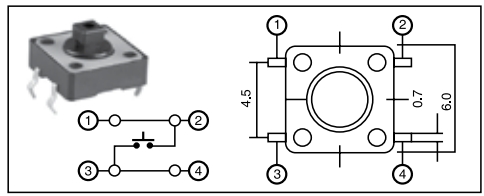


Fig. 50: Tactile switch photo, circuit and its plan view

2. Loudspeaker

Fig. 51 (a): Loudspeaker

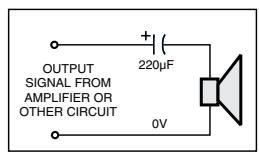


Fig. 51 (b): Connecting speaker via capacitor

3. Piezo Buzzer

Fig. 52: Piezo buzzer and its symbol

4. Diodes

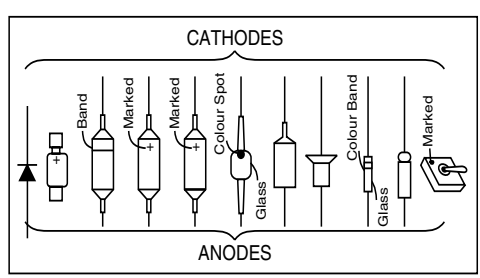


Fig. 53: Diode symbols and various physical configurations

5. Light emitting diode (LED): Fig. 54 shows the anatomy of an AlGaInP [aluminium (Al), gallium (Ga), indium (In) and phosphide (P)] LED.

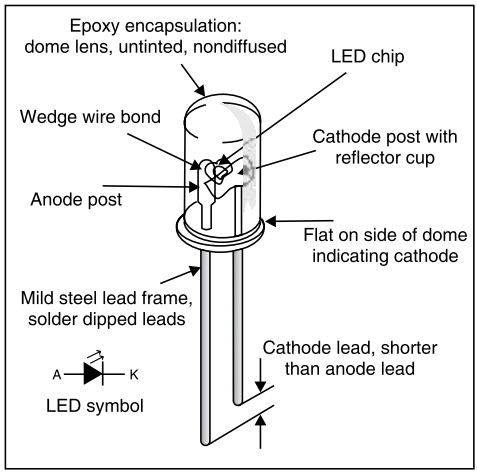


Fig. 54: Parts of an LED

6. 7-Segment LED display: Fig. 55 shows the standard arrangement of segment LEDs (for common-cathode and common-anode displays) and corresponding DIP pin numbers (spacing 2.54 mm). The spacing between the two rows of pins is a function of digit size.

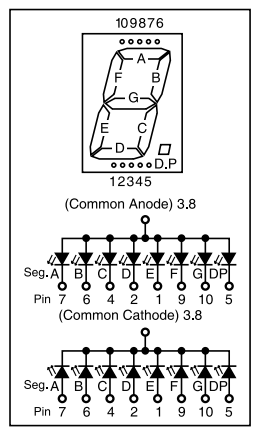


Fig. 55: 7-Segment LED display

7. DIL (dual-in-line)/DIP (dual-inline-pins) switch: This is a set of miniature SPST on-off switches. These switches use the same base configuration as the DIP ICs (refer Fig. 56) with pin-to-pin spacing of 2.54mm (0.1"). These are commonly available as 4-way, 6-way and 8-way SPST switches. When a switch is flipped (with finger nail or screwdriver tip) toward 'on' side, the opposite pins are shorted, while in the 'off' position they are open.

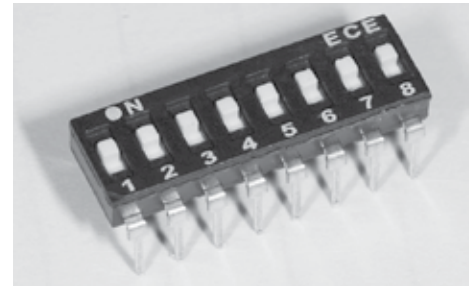


Fig. 56 (a): 8-way DIP switch

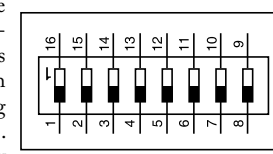


Fig. 56 (b): Pin numbering of 8-way DIP switch

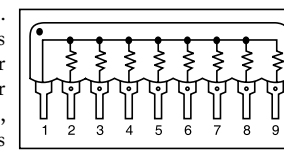


Fig. 57: SIL/SIP 8-resistor network

8. SIL (single-in-line)/SIP (single-inline-pins) RNW (resistor network): This is one of the more popular resistor configurations for saving space on a PCB, when one side of each resistor is to be connected to a common point (e.g., ground or positive or negative rails) and the resistors are of equal value, e.g., 100-kilo-ohm each. The normal wattage is 1/8W. The pin-to-pin spacing is again 2.54 mm (0.1"). For 8-resistor NW, there are 9 pins, as shown in Fig. 57. Pin 1, marked with a black circle or tapered end, depicts the common pin.

Stabilised power supply

For wiring and experimenting with various circuits that are described in part II of this booklet, we should build a stabilised power supply circuit (Fig. 58), which may be connected directly to 230V AC mains supply and can provide us with the desired adjustable output DC voltages from 3V to 12V for connection to the prototyping board. The power supply circuit is to be wired on a proper PCB.

TABLE 3
Output voltage vs equivalent series resistance Rx

Output Voltage	12V	9V	6V	5V	3V
Series equivalent resistor (Rx) in ohms	1900	1353	838	655	323

Circuit description: AC mains 230V AC is down converted to 15V AC by the step-down transformer X1, the secondary winding of which can support a current of 2 amperes. A bridge rectifier converts the AC to pulsating DC with a peak voltage level of 21V (15x1.4142). LED1 lights up to indicate availability of output from the rectifier. The 2.2 kilo-ohm resistor R1 limits the current through LED1 to a value below 10mA (milli-ampere). The output from bridge rectifier is smoothed by 470µF capacitor C1. C2 is used for bypassing high frequency ripple.

The LM317T series of adjustable 3-terminal positive voltage regulator is used at the output of rectifier section. It is capable of supplying in excess of 1.5A over a 1.2V to 37V output voltage range. However, here it has been used to supply discrete voltages of 3V, 5V, 6V, 9V and 12V with the help of a 5-way rotary switch S2, which brings in different value resistors between Adj pin of the regulator and ground, while the resistor R2 (between Adj pin and output pin) is a fixed 220-ohm resistor.

The output voltage Vo is given by the relation:

$$Vo \approx 1.25(1+Rx/R2)$$

where Rx is the resistance connected between Adj pin of regulator and ground.

In 12V position of the switch (off position), the value of Rx=R3+R4=1900 ohm, while in various other positions it is the equivalent of 1900 ohm in shunt with another resistance shown in circuit. Table 3 shows the equivalent series resistance in various positions of the rotary switch.

Discrete resistor (with 1% tolerance) switching is preferred to a variable resistor here, since wiper contact becomes erratic after some use and the tolerance (variation with temperature) of a variable resistor is also much higher.

The LM317T regulator is to be fitted with a heatsink between the regulator and printed circuit board to provide the best heat transfer. Note that the higher the load current or lower the voltage across the load, the

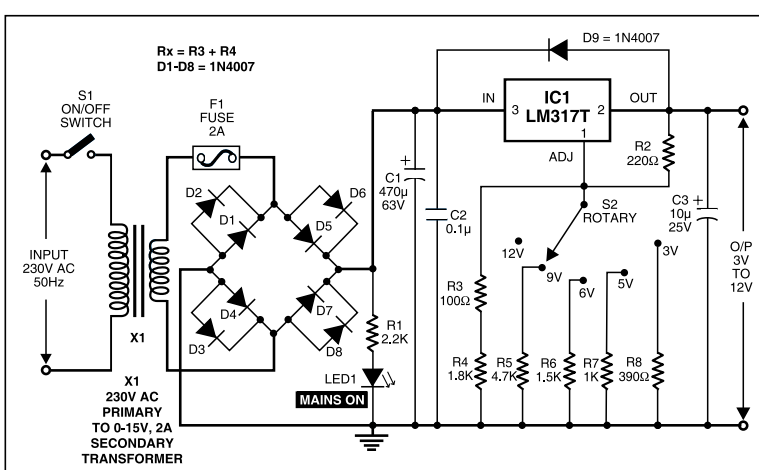


Fig. 58: Discretely adjustable 1.5A stabilised power supply

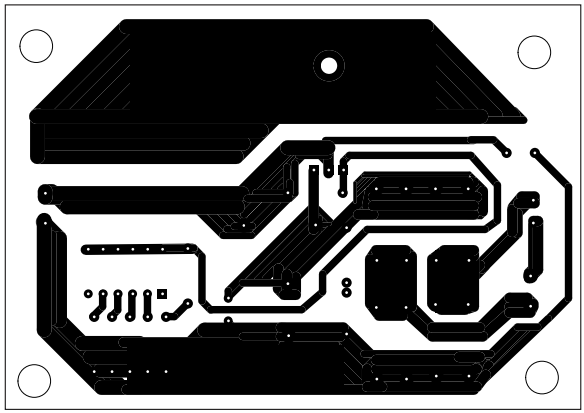


Fig. 59: PCB layout

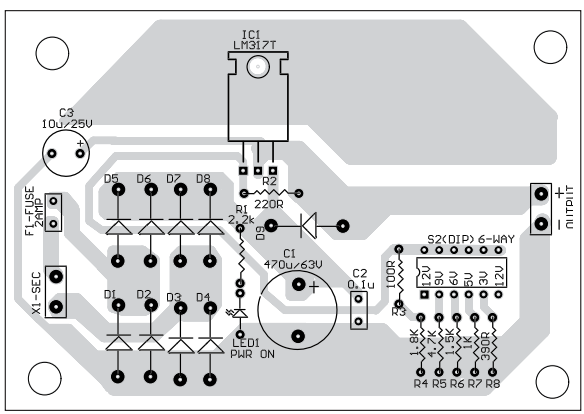


Fig. 60: Component layout

higher will be the heat dissipation at the regulator. Assuming that you adjust the output to be 3-volt and the load draws a current of 1.5A, then approximately 10 volt is dropped across IC1. The power dissipation at IC1 = 10×1.5=15 watt. To dissipate this heat you must use a heatsink of size 4 cm×10 cm or so.

A 3mm aluminium plate of the mentioned size screwed to the regulator will work as an efficient heatsink. A minimum voltage differential of 3V to 4V between input and output voltage is essential for proper regulation.

Actual-size PCB track-side layout and component layouts are shown in Figs. 59 and 60, respectively.

PART LIST

Semiconductors

IC1	- LM317T	- 1.5A adjustable regulator
D1-D9	- 1N4007	- rectifier diode
LED1	- 5mm	- red LED

Resistors

R1	- 2.2 kilo-ohm	- 0.25W, 1% MFR
R2	- 220-ohm	- 0.25W, 1% MFR
R3	- 100-ohm	- 0.25W, 1% MFR
R4	- 1.8 kilo-ohm	- 0.25W, 1% MFR
R5	- 4.7 kilo-ohm	- 0.25W, 1% MFR
R6	- 1.5 kilo-ohm	- 0.25W, 1% MFR
R7	- 1 kilo-ohm	- 0.25W, 1% MFR
R8	- 390-ohm	- 0.25W, 1% MFR

Capacitors

C1	- 470µF, 63V electrolytic
C2	- 0.1µF ceramic disk
C3	- 10µF, 25V electrolytic

Miscellaneous

X1	- 230V AC primary to 15V AC, 2A secondary transformer
S1	- Switch toggle, SPST
F1	- Fuse cartridge, 2A (with holder)
S2	- Switch rotary, single-pole 5-way (in lieu DIP switch 6-way)
	- Heatsink
	- Box for mounting hardware and PCB
	- LED holder
	- Tag blocks for input
	- Screwable binding posts for output connection
	- Screws with nuts and washers
	- Insulated spacers for mounting PCB

Switch S1, transformer X1, LED1 and fuse F1, and rotary switch S2 are preferably mounted suitably in a metallic box. Heatsink (aluminium sheet) is to be inserted flat between the regulator and the PCB, and secured by using a nut and bolt after applying some heatsink paste on the metal portion of LM317T. In Fig. 60 we have shown a 6-way DIP switch, but you should preferably use a rotary switch mounted on the box and extend the connections from DIP switch (corresponding points) to the rotary switch position with a common connection going to the pole of the rotary switch. In case you use the DIP switch combination, then for selecting the desired voltage, only one switch (out of 6 switches) should be 'on,' i.e., closed, and all other switches should be 'off,' i.e., open. As LM317T has built-in short circuit protection, no fuse at its output is necessary.

Versatile CMOS/TTL logic and clock probe with audio-visual indication

For fault diagnosis of any logic circuit, what you essentially need is a probe that can test the logic level or existence of clock activity. The circuit shown in Fig. 61 can be used to test CMOS and TTL logic circuits for the logic states, and also for presence of clock activity from a few hertz to more than 10 MHz, at any point on the logic circuit.

Supply for the probe circuit is taken from the circuit under test using crocodile clips. In the circuit, LM339 dual-comparator is connected as a window detector. The non-inverting pin of comparator N1 is biased to nearly 2V when switch S1 is in TTL position and 80% of Vcc is in CMOS position. The output of N1 goes low only when logic input at probe tip exceeds the biasing voltage, and as a result red LED lights to indicate logic 1 state

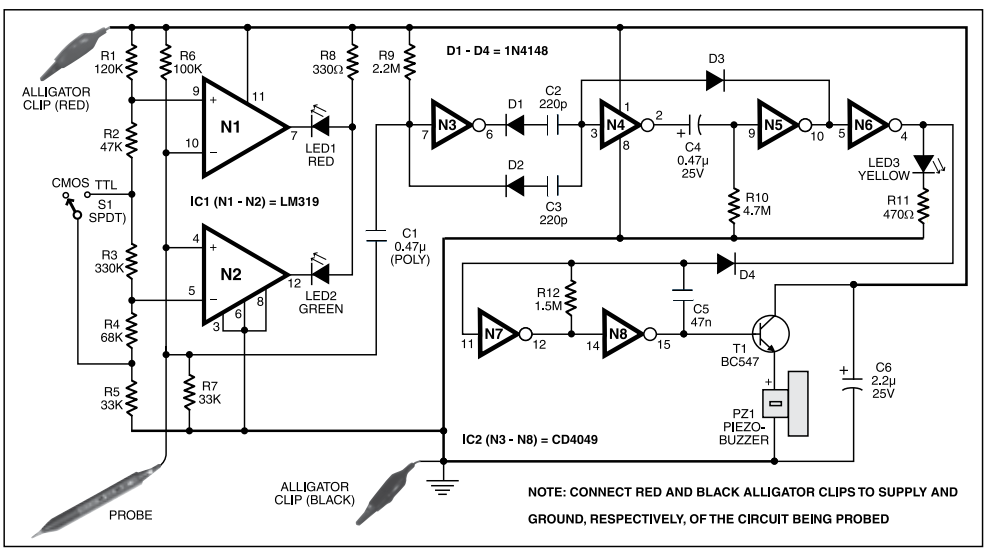


Fig. 61: Circuit for CMOS/TTL logic and clock probe with audio-visual indication

TABLE 4

Test summary CMOS/TTL logic and clock functions

Test conditions	Specified level	Observed level	Red LED	Green LED	Yellow LED	Buzzer sound
TTL (5V)						
Low	**<0.8V**	**<0.8V**	**Off**	**On**	**Off**	**Off**
High	**>2V**	**>=2.1V**	**On**	**Off**	**Off**	**Off**
Clock	**TTL Compatible**	**1Hz-To >10MHz**	**Off**	**Momentarily On**	**On for (3-Sec)**	**On for (3-Sec)**
CMOS(12V)						
Low	**<2.5V**	**<=2.35V**	**Off**	**On**	**Off**	**Off**
High	**>9.5V**	**>9.5V**	**On**	**Off**	**Off**	**Off**
Clock	**CMOS Compatible**	**1Hz-To >10MHz**	**Off**	**Momentarily On**	**On for (3-Sec)**	**On for (3-Sec)**

PARTS LIST

Semiconductors		
IC1 (N1-N2)	- LM319 dual comparator	
IC2 (N3-N8)	- CD4049 CMOS hex inverter	
T1	- BC547 npn transistor	
D1–D4	- 1N4148 switching diode	
LED1–LED3	- 5mm red, green and yellow LEDs	
Resistors		
R1	- 120-kilo-ohm	- 0.25W, 1% MFR
R2	- 47-kilo-ohm	- 0.25W, 1% MFR
R3	- 330-kilo-ohm	- 0.25W, 1% MFR
R4	- 68-kilo-ohm	- 0.25W, 1% MFR
R5, R7	- 33-kilo-ohm	- 0.25W, 1% MFR
R6	- 100-kilo-ohm	- 0.25W, 1% MFR
R8	- 330-ohm	- 0.25W, 5% carbon
R9	- 2.2-meg-ohm	- 0.25W, 5% carbon
R10	- 4.7-meg-ohm	- 0.25W, 5% carbon
R11	- 470-ohm	- 0.25W, 5% carbon
R12	- 1.5-meg-ohm	- 0.25W, 5% carbon
Capacitors		
C1, C4	- 0.47µF	- polyester
C2, C3	- 220pF	- ceramic disk
C5	- 47nF	- ceramic disk
C6	- 2.2 µF, 25V	- electrolytic
Miscellaneous		
S1	- SPDT	- slide-switch
PZ1	- Piezo buzzer	- 3 to 12V mini buzzer
	- Probe	- pin type meter probe
	- Alligator clip	- one black and one red (insu lated)

at probe tip.

Similarly, inverting pin of comparator N2 is biased at nearly 0.8 V (in TTL position of switch S1) and 20% of Vcc (in CMOS position of switch S1). Only when the input voltage at probe tip is less than the biasing voltage will its output drop low to light up the green LED to indicate logic 0 state.

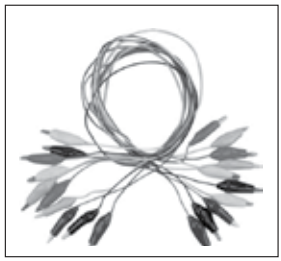


Fig. 62: Pairs of miniature insulated crocodile clips.

The probe tip is also connected to CD4049 (N3) input via capacitor C1 to pass AC/clock signals. It simply acts as a buffer and couples only the high-to-low going signals at input/output of the gate to the input of next gate N4. Output of gate N4 is further coupled to gate N5, which is wired as a monostable.

A positive feedback from output of gate N5 to input of gate N4 ensures that unless capacitor C4 (0.47µF) discharges sufficiently via the 4.7M

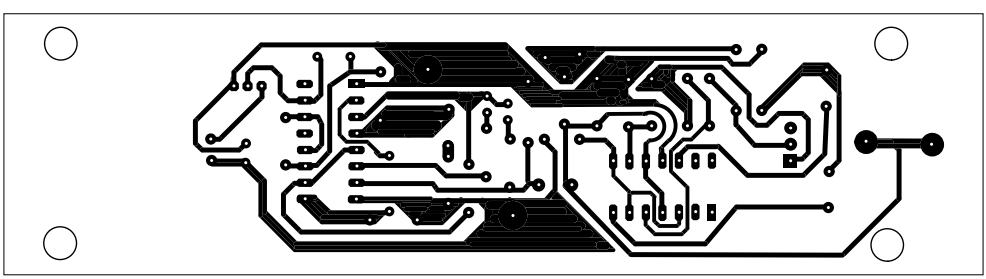


Fig. 63: Actual-size track side of probe PCB

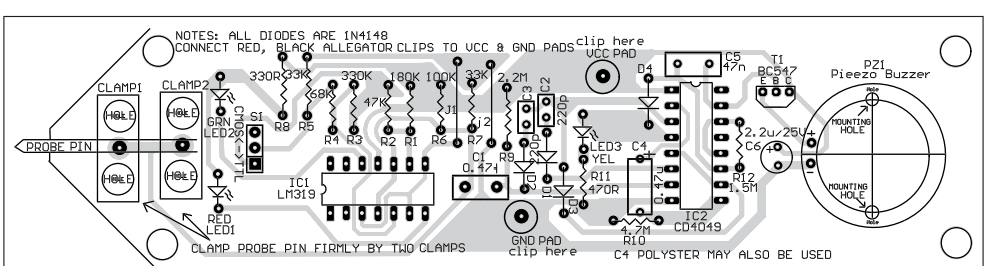


Fig. 64: Component layout of probe PCB

resistor, further clock pulses at the input of N4 will have no effect. Gate N6 is used for driving a yellow LED (indicating oscillatory input at probe tip), which will be switching on for a brief period. Gate N6 output is also used to inhibit/enable the oscillator formed by gates N7 and N8. It briefly activates the buzzer to beep during the mono period, indicating oscillatory input at probe tip. Thus we have audiovisual indication during clock/oscillatory input at probe tip. Table 4 summarizes the test results.

Fig. 62 shows the type of miniature, insulated crocodile clips which may be used for connection to supply and ground pads of the PCB. The actual-size PCB and its component layout are shown in Figs. 63 and 64, respectively. The probe PCB after assembly could be suitably placed inside a plastic pencil box with probe pin protruding out. Small holes in the case could be made for the three LEDs. The probe pin should be firmly clamped using plastic clamps, cut from a plastic cable tie or any plastic sheet. ●

PART II
Electronics Projects

SECTION 1
Melody generator projects based on UM66TXXX IC

General description

The UM66TXXX series is a CMOS (complementary metal oxide semiconductor) LSI (large scale integration) 3-pin chip in TO-92 (transistor-type) package. It is designed for use in door bells, telephones, toys, greeting cards and similar applications. It has an on-chip ROM (read-only-memory) programmed for generating musical tones/ notes.

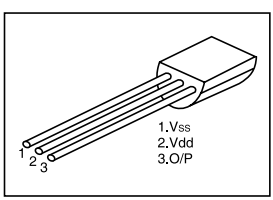


Fig. 1.1: Pin-out of UM66TXXX

Front view of the IC UM66 is shown in Fig. 1.1. Pin 1 (Vss) is for negative supply, pin 2 (Vdd) is for positive supply and pin 3 (O/P) is for music output. Typical Vdd value is +3V with Vss at ground potential (0V). Please follow this pin configuration of UM66 IC in all circuits published in this book.

Features

- 64-note ROM memory
- One-shot mode for playing once (S-mode)
- 1.3V to 3.3V supply
- Level-hold mode to play repeatedly (L-mode)
- Built-in RC oscillator
- It can directly drive a piezo element
- Can drive a dynamic speaker with an external npn transistor

XXX suffix

The first two XX digits of part number are substituted with song number (01, 02 and so on–refer partial list shown below). The third X indicates mode, i.e., when it is substituted with S, it indicates that chip is pre-programmed for one-shot mode. L indicates repeat (level-hold) mode. Examples:

Part No.	Song
UM66TOl L/S	Jingle Bells/Santa Claus is Coming to Town/ We Wish You a Merry X'mas
U M66T02 L/S	Jingle Bells
U M66T04 L/S	Jingle Bells/Rudolph, the Red-nosed Reindeer/Joy to the World
UM66T05 L/S	Home Sweet Home
UM66T06 L/S	Let Me Call You Sweetheart
UM66T08 L/S	Happy Birthday to You

Here are some basic application circuits using UM66T XXX chips that you can wire up and experiment with.

Project 1
A simple melody player

This circuit (Fig. 1.2) for driving a UM66TXXL (repeat mode) can directly drive a piezo buzzer element using a 1.5 to 3 volts battery (i.e., one to two cells in series). The 1 mode chip will repeatedly play the song as long as switch S1 is kept 'on.'

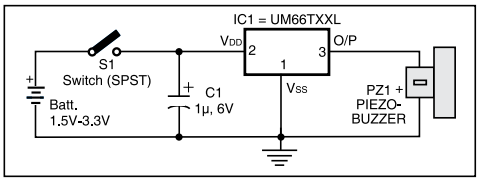


Fig. 1.2: Simple melody player

PARTS LIST		
IC1	-	UM66TXXL melody generator (repeat mode)
C1	-	1µF, 6V electrolytic capacitor
S1	-	toggle switch, single-pole-single-throw type
PZ1	-	piezo buzzer
Batt.	-	1.5V x 2 battery cells can be used in lieu of DC power supply of Part I

Project 2
Melody player using a speaker

The circuit (Fig. 1.3) of the melody player using a speaker is almost the same as that of simple melody player shown in Fig. 1.2, except that a transistor is used as a driver to increase the drive capability for sourcing higher current for the speaker. Resistor R1 is selected so as to avoid excessive load on output pin of the melody generator and limit the base drive to transistor T1. Additional parts (compared to Project 1) used are shown in the parts list.

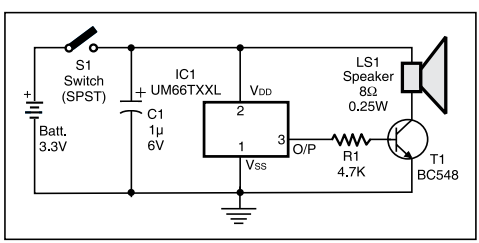


Fig. 1.3: Melody player using a speaker

ADDITIONAL PARTS LIST				
LS1	-	8-ohm, 250mW	-	miniature speaker
T1	-	BC548	-	npn transistor
R1	-	4.7-kilo-ohm	-	resistor, 0.25W

Modification of circuits for using UM66TXXS (single shot): If you are using the single shot version of the melody generator (suffix S), then the circuits in Figs. 1.2 and 1.3 need to be slightly modified as follows:

(a) Substitute a 220-ohm resistor for existing SPST switch S1.

(b) Place a normally open tactile switch (push-to-on) across capacitor C1.

Every depression of tactile switch will cause the song/tune to be played once.

Thus, additional parts required are:

Resistor 220-ohm Qty. one

Tactile switch (N/O) Qty. one

Here are some simpler and interesting circuits employing UM66T IC that have appeared in EFY over a period of time. Some of them have been modified to improve the circuit operation.

Project 3
Musical call bell

This musical bell can be operated by just bridging the gap between the touch plates with one's fingertips. Thus there is no need for a mechanical on/off switch because the touch plates act as a switch. The bell can work on 3V (two pencil cells), and can be used in homes and offices.

A complementary pair of transistors (BC548, npn type and BC558, pnp type) forms a very high gain

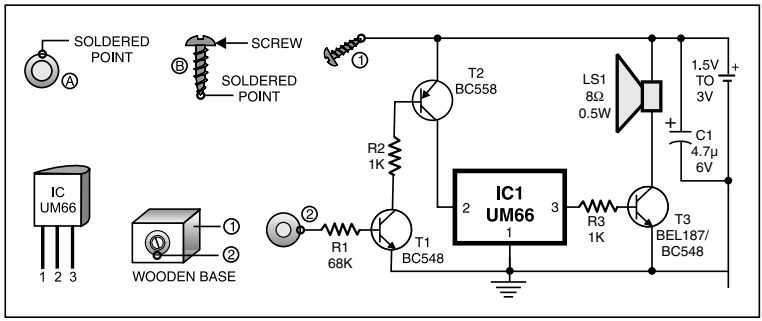


Fig. 1.4: Musical call bell schematic circuit

PARTS LIST

IC1	- UM66TxxL	- melody generator
T1, T3	- BC548	- npn transistor
T2	- BC558	- pnp transistor
R1	- 68-kilo-ohm	- resistor, 0.25W
R2, R3	- 1-kilo-ohm	- resistor, 0.25W
C1	- 4.7µF, 6V	- capacitor, electrolytic
LS1	- 8Ω, 0.5W	- loudspeaker
	- Brass screw and washer	
	- Pencil cells 1.5Vx2	
	- Wooden piece	

amplifier for sensing the finger touch and switching on a melody IC. The emitter of npn transistor BC548 is shorted to the ground, while that of transistor BC558 is connected to the positive terminal. The collector of transistor BC548 is connected to the base of BC558 via current limiting resistor R2. The base of BC548 is connected to the washer through another current limiting resistor R1 (as shown in the figure). The collector of BC558 is connected to Vdd pin 2 of musical IC UM66, and its Vss pin 1 is shorted to the ground. The output from pin 3 is connected to a transistor amplifier comprising BEL187 transistor for feeding the loudspeaker.

The positive supply rail connected to the emitter of pnp transistor T2 is extended and soldered to a brass screw, while the brass washer is soldered to one end of resistor R1, whose other end is connected to base of npn transistor T1 (as shown in the figure). The 1.5V or 3V (single pencil cell or two pencil cells) can serve as power supply for the circuit.

When the touch-plate gap between brass screw and washer (insulated from each other) is bridged with a fingertip, the emitter-collector junction of transistor BC548 starts conducting. Simultaneously, the emitter of transistor BC548 gets forward biased and it starts conducting. This results in transistor BC548 collector pulling toward ground potential, and hence the pnp transistor BC558 conducts and its collector is pulled towards the positive rail, which thus activates melody generator IC1 (UM66). The output of IC1 is amplified by transistor BEL187 and fed to the speaker. So we hear a musical note

Note that the brass washer's inner diameter should be about 1 mm greater than that of the screw head. The washer can be fixed in desired position on wooden base by using an insulating adhesive (such as Elfy or Feviquick). The screw should be fitted within the washer, ensuring that there is an all-round gap between the washer and screw head.

Project 4
Musical hold-on for telephone

This external add-on circuit can be connected to any telephone without affecting its normal operation. By using this circuit, one can hold on to a line with the flick of a switch without giving the other-end subscriber any cause for complaint as he/she can enjoy some pleasant music during the hold-on period. Another flick of the same switch releases the held line.

Diodes D1 to D4 form a bridge rectifier circuit, which is connected across the telephone lines. Transistor T1 is a high voltage transistor, which

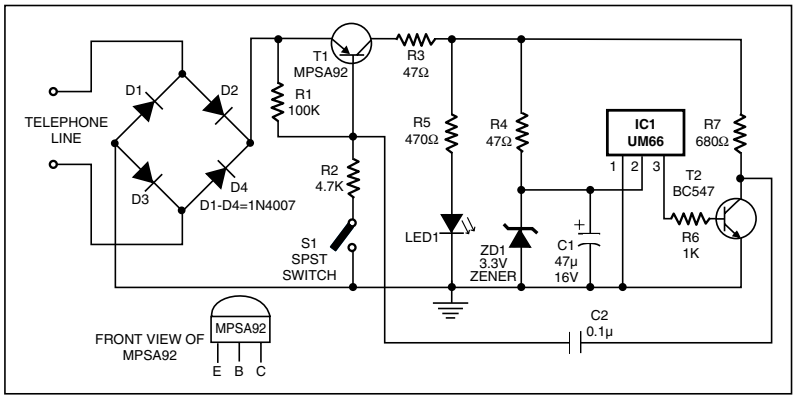


Fig. 1.5: Schematic circuit of musical hold-on for telephone

PARTS LIST		
IC1	- UM66TxxL	- melody generator
T1	- MPSA92	- pnp high-voltage transistor
T2	- BC547	- npn transistor
D1–D4	- 1N4007	- rectifier diode
ZD1	- 3.3V, 1W	- zener diode
LED1	- 5mm	- red LED
R1	- 100-kilo-ohm	- resistor, 0.25W
R2	- 4.7-kilo-ohm	- resistor, 0.25W
R3, R4	- 47-ohm	- resistor, 0.5W
R5	- 470-ohm	- resistor, 0.25W
R6	- 1-kilo-ohm	- resistor, 0.25W
R7	- 680-ohm	- resistor, 0.25W
C1	- 47µF, 16V	- capacitor, electrolytic

works as an electronic switch cum amplifier. Resistors R3, R4, capacitor C1 and zener diode ZD1 form a voltage regulator for UM66, which is used as a music generator.

As long as switch S1 remains open, nothing really happens, since the base and emitter of MPSA92 transistor are both at the same potential and hence it is cut off. However, when S1 is switched on, transistor T1 gets forward biased via the potential divider consisting of resistors R1 and R2. This results in the DC voltage from the telephone line being applied to the regulator circuit. On conduction of transistor T1, LED1 lights up via resistor R5. Simultaneously, the voltage developed across zener-capacitor C1 combination activates the melody generator UM66. The musical signal appearing at the collector of transistor T2 is coupled to the base of transistor TI via capacitor C2 and then to the telephone line through transistor T1 as long as switch S1 is on. When switch S1 is flipped to off state, the normal telephone conversation can resume.

Project 5
Timer with musical alarm

This timer can be used for introducing a delay of one minute to two hours. After the set timing period is over, a musical song is played.

The circuit as shown in Fig. 1.6 is built around CMOS oscillator/divider CD4060 (IC1). Before proceeding with the description, here is an introduction to CD4060, which contains a 14-stage ripple counter and a free NAND and NOT gate which can be used to wire up an oscillator. A functional block diagram of 4060 with NAND and NOT gates wired externally is shown in Fig. 1.7.

In this16-pin IC, outputs Q0 (divide-by-2) through Q2 (divide-by-8) and Q10 (divide-by-2048) are not brought out on external pins. The frequency of oscillations is given by the equation:

$f_{osc} = \frac{1}{2.3 \times R_T \times C_T}$ *and its time period T from the relationship* $T = \frac{1}{f}$

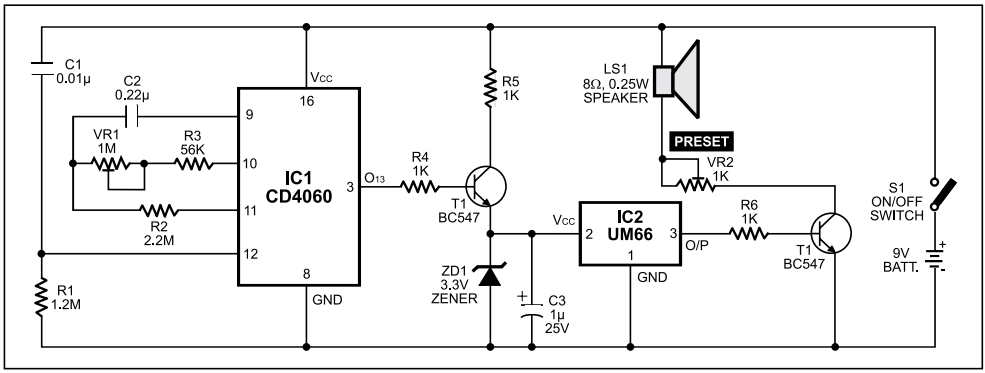


Fig. 1.6: Schematic circuit of timer with musical alarm

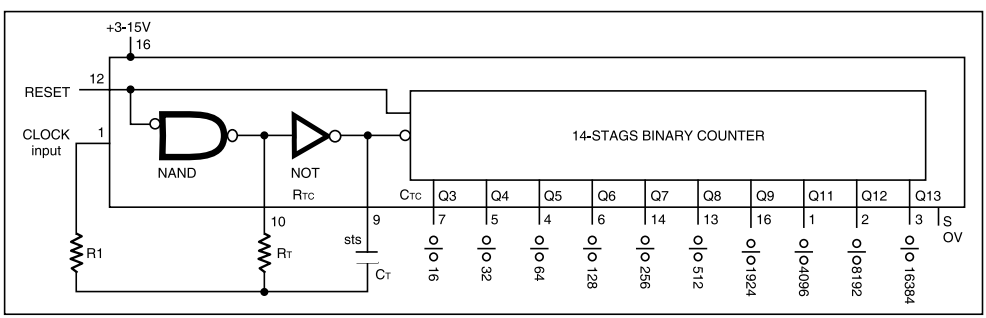


Fig. 1.7: Functional block diagram of CD4060 with oscillator wired up externally.

PARTS LIST		
IC1	- CD4060	- 14-bit ripple counter and oscillator
IC2	- UM66	- melody generator
T1, T2	- BC547	- npn transistor
ZD1	- 3.3V	- zener diode, 0.5W
R1	- 1.2-mega-ohm	- resistor, 0.25W
R2	- 2.2-mega-ohm	- resistor, 0.25W
R3	- 56-kilo-ohm	- resistor, 0.25W
R4-R6	- 1-kilo-ohm	- resistor, 0.25W
VR1	- 1-mega-ohm	- resistor, preset
VR2	- 1-kilo-ohm	- resistor, preset
C1	- 0.01µF	- capacitor, ceramic disk
C2	- 0.22µF	- capacitor, ceramic disk
C3	- 1µF,25V	- capacitor, electrolytic
S1	- SPST	- toggle switch
LS1	- 8-ohm, 0.25W	- miniature speaker
Bat.	- 9V, PP3	- battery with holder

provided that R1>>R_T. Here R1 and R_T are in ohm and C_T is in Farad. The frequency gets divided (or input clock period gets multiplied) by the factors as indicated at various pins in Fig. 1.7. You can easily work out the frequency (f_{OSC}) or its time period and the delayed output period at various pins of CD4060 from the values of R_T and C_T.

The circuit in Fig. 1.6 works off a 9V PP3 battery and its standby current drain is very low. The desired time delay can be set by adjusting preset VR1. After preset time delay, output pin 3 of IC1 goes high and npn transistor T1 conducts to extend positive supply rail to the melody generator IC UM66 (IC2) at its pin 2.

Zener diode ZD1 steps down the 9V power supply to the required 3.3V level for operation of UM66 melody generator. The output of UM66 is amplified by transistor T1 to drive the loudspeaker. Preset VR2 is used to control the volume of the music output from the loudspeaker. The timer gets activated/deactivated simply by switching on/off the power supply switch S1.

Project 6
Intercom with musical ringtone

A low-cost, two-way intercom circuit with a musical ringtone can be made using readily available components. Melody generator IC UM66 (IC1) generates a ringtone for the intercom circuit. The supply voltage to IC1 is limited to 3.3 volts by the zener diode. In the intercom circuit shown in Fig. 1.8, LM386 (IC2) amplifies the signal received from either the condenser microphone or the output of UM66.

IC LM386 is an audio low-power 8-pin IC. It is available with output power ratings of 300 mW (suffix N1), 500 mW (suffix N3) and 700 mW (suffix N4). A pinout diagram is shown in Fig. 1.9. It can operate from 5V to 15V DC supply. With pins 1 and 8 left open, it gives a gain of 20 dB. However, when a capacitor of 10µF is placed across these pins, 1 (+ve) and 8 (-ve), its gain becomes 200dB as in the present circuit in Fig. 1.8.

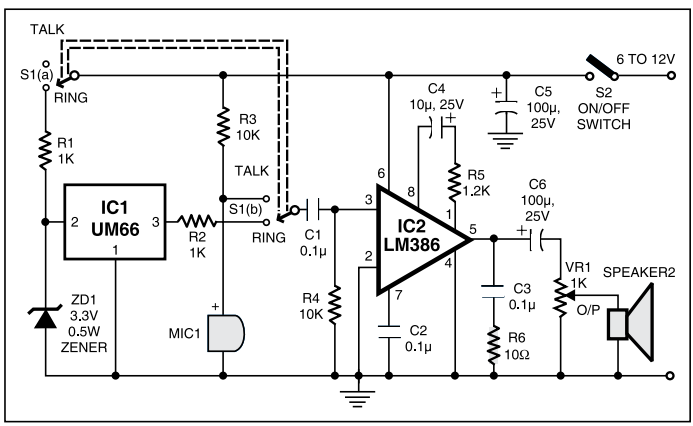


Fig. 1.8: One-end circuit of intercom with musical ring tone (identical circuit for the other end)

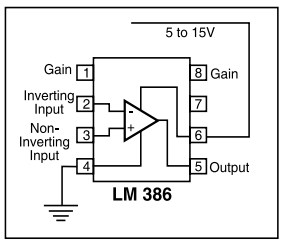


Fig. 1.9: LM386 pin configuration

The speaker volume is adjusted with the help of VR1. For two-way intercom operation, make two identical units and connect them as shown in Fig. 1.10. The output of one unit goes to the speaker of the other unit, and vice versa. If you use separate power supplies for the two units, a 3-core cable (two wires for outputs and one wire for common ground) is needed for intercom connection.

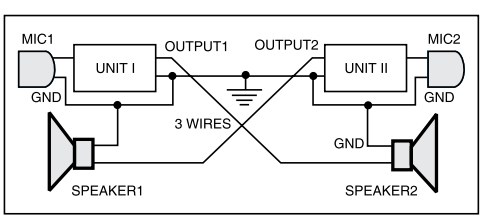


Fig. 1.10: Wiring diagram of complete intercom (unit I and unit II).

PARTS LIST

IC1	- UM66TxxL	- melody generator
IC2	- LM386	- low-power audio amplifier
ZD1	- 3.3V, 0.5 W	- zener
R1, R2	- 1-kilo-ohm	- resistor, 0.25W
R3, R4	- 10-kilo-ohm	- resistor, 0.25W
R5	- 1.2-kilo-ohm	- resistor, 0.25W
R6	- 10-ohm	- resistor, 0.25W
VR1	- 1-kilo-ohm	- potmeter wirewound
C1-C3	- 0.1µF	- capacitor, ceramic disk
C4	- 10µF, 25V	- capacitor, electrolytic
C5, C6	- 100µF, 25V	- capacitor, electrolytic
S1	- SPDT	- switch, spring loaded
S2	- SPST	- switch, toggle
	- Mic	- condenser microphone
	- 8-ohm, 0.5W	- speaker

Project 7
Soft musical telephone ringer

The normal telephone bell can at times disturb one's peace (especially during the night). The circuit shown here converts the loud bell into a soft and pleasing musical tone. The incoming telephone ring is detected by transistor T1 and the components wired around it.

In the absence of ringing voltage, transistor T1 is cut off while transistor T2 is forward biased, as resistor R2 is returned to the positive supply rails. As a result, collector of transistor T2 is at near-ground potential and hence IC1 (UM66) is 'off.' Also, capacitor C2 is charged to a slightly positive potential.

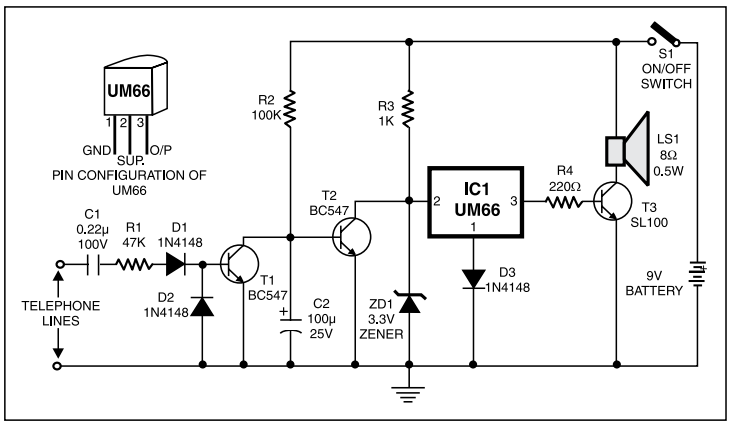


Fig. 1.11: Soft musical telephone ringer

During the positive half of the ringing voltage, diode Dl forward biases transistor T1 and rapidly discharges capacitor C2 to near ground potential. It cuts off transistor T2 which, in turn, causes IC1 to be forward biased. The music signal is applied to base of transistor T3, which drives the speaker. During the negative half of the ringing voltage, capacitor C2 cannot charge rapidly via resistor R2 and hence transistor T2 remains cut off during the ringing interval. Thus, the soft musical note into the loudspeaker is synchronous with the ringing signal. When the handset is lifted off the cradle, the ringing voltage is no more available and the musical note switches off.

PARTS LIST

IC1	- UM66TxxL	- melody generator
T1, T2	- BC547	- npn transistor
T3	- SL100	- npn transistor
D1-D3	- 1N4148	- switching diode
ZD1	- 3.3V, 0.5W	- zener diode
R1	- 47-kilo-ohm	- resistor, 0.25W
R2	- 100-kilo-ohm	- resistor, 0.25W
R3,R4	- 1-kilo-ohm	- resistor, 0.25W
C1	- 0.22µF, 100V	- capacitor, polyester
C2	- 100µF, 25V	- capacitor, electrolytic
S1	- SPST	- toggle switch
LS1	- 8-ohm, 0.5W	- loudspeaker
	- 9V	- battery with holder

Project 8
Touch-sensitive musical bell with delay

This circuit is built around CMOS IC CD4011 and popular melody generator IC UM66. When touch plates are bridged by hand for a moment, the circuit starts to generate music. After a few seconds, the music automatically stops. This circuit can work from a power supply of regulated 5V to 6V. Diodes D1 through D3 are used to drop around 2V, as maximum supply to UM66 is limited to 5V.

In its quiescent state, transistor T1 is cut off as

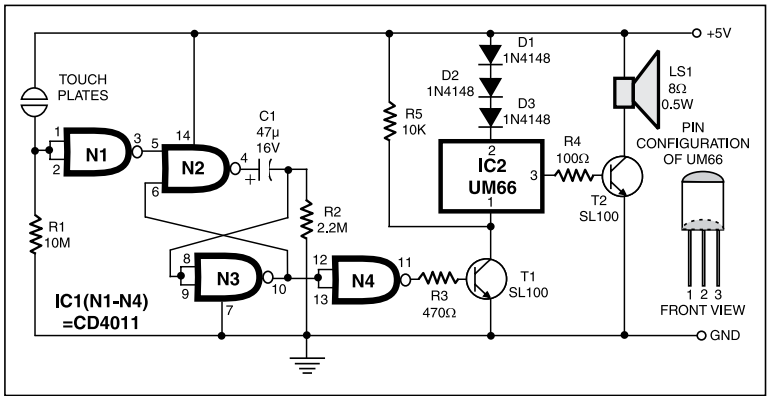


Fig. 1.12: Touch-sensitive musical bell with delay

PARTS LIST		
IC1	- CD4011	- quad 2-input NAND CMOS IC
IC2	- UM66TxxL	- melody generator
T1, T2	- SL100	- npn transistor
D1-D3	- 1N4148	- switching diode
R1	- 1-mega-ohm	- resistor 0.25W
R2	- 2.2-mega-ohm	- resistor 0.25W
R3	- 470-ohm	- resistor 0.25W
R4	- 1-kilo-ohm	- resistor 0.25W
R5	- 10-kilo-ohm	- resistor 0.25W
C1	- 47µF, 16V	- capacitor electrolytic
LS1	- 8-ohm, 0.5W	- loudspeaker
		- metallic touch plates
		- 5V regulated power supply

NAND gate N3 input pins are returned to ground via resistor R2. This input after two inversions (by NAND gates N3 and N4) biases off transistor T1 to cut off. Since Vss pin 1 of UM66 IC is returned to positive supply through resistor R5, it remains inactive.

When a person bridges the gap between touch plates with his fingers, input to NAND gate N1 goes from ground to positive potential. The output of N1 gate goes low, which forces the output of gate N2 to go high. This high voltage appears initially across resistor R2 and input of gate N3. The high input voltage at gate N3, after double inversion by N3 and N4, results in forward biasing of transistor T1, pulling its collector toward grounds, and thus activating the melody generator IC UM66. Output of UM66 amplified by transistor T2 drives the loudspeaker. The melody generater remains 'on' until potential across R2 exponentially drops to cut off gate N3. This time delay can be changed by changing the values of capacitor C1 and/or resistor R2.

(*Note*. For detailed explanation of working of NAND gate CD4011, please refer to section 2).

Project 9
Musical continuity tester

The circuit described here is very useful in checking the continuity of low resistance coils, speakers, IFTs, small audio transformers, etc. A special feature of this continuity tester is a low supply voltage (2-3V) and a low quiescent current (1.5mA at 3V).

In the circuit for continuity tester, IC1 TLC251 (or TLC271) is an op-amp, wired as a comparator. When an external low resistance is connected across the probes, output of IC1 goes high and as a result IC2 UM66, the popular melody generator, gets supply voltage. Music signals generated at the output of IC2 are amplified by transistor Tl, which drives a low-wattage speaker. This continuity tester can be used to check low resistances only (and not high resistances or semiconductor devices).

TLC251 op-amp can function satisfactorily with a supply voltage range between 1.4V and 16V(in single or dual supply configuration). If nulling (i.e., 0V output for 0V between input pins) is desired, the arrangement

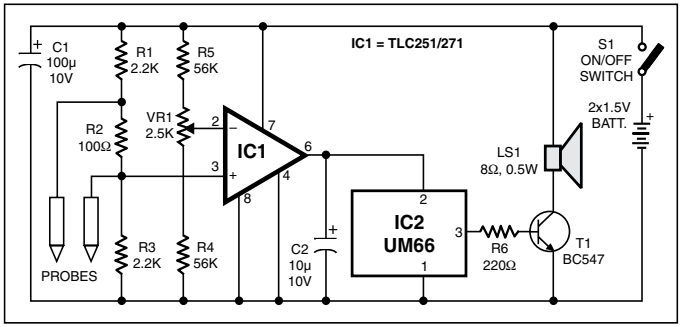


Fig. 1.13: Musical continuity tester

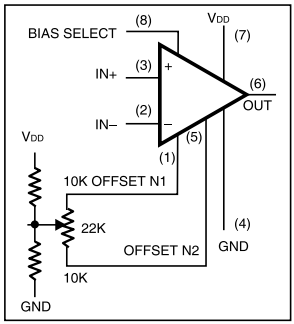


Fig. 1.14: TLC251 nulling method

PARTS LIST		
IC1	- TLC251	- opamp
IC2	- UM66TXXL	- melody generator
T1	- BC547	- npn transistor
R1,R3	- 2.2 kilo-ohm	- resistor, 0.25W
R2	- 100-ohm	- resistor, 0.25W
R4,R5	- 56- kilo-ohm	- resistor, 0.25W
R6	- 1- kilo-ohm	- resistor, 0.25W
VR1	- 2.5-kilo-ohm	- preset
C1	- 100µ, 10V	- capacitor, electrolytic
C2	- 10µ, 10V	- capacitor, electrolytic
S1	- SPST	- switch, toggle
LS1		- loudspeaker 8-ohm, 0.5W
		- battery cell 1.5V×2
		- meter probes, one pair

TABLE 1-1

Recommended biasing voltages

Bias Mode	AC Performance	Bias Pin Voltage	Typical I_{DD}
Low	Low	V_{DD}	10µA
Medium	Medium	0.8V to 9.2V	150µA
High	High	Ground Pin	1000µA

shown in Fig. 1.14 may be used. Bias Select pin allows the selection of one of three I_{DD} (supply current) conditions—(10µA (low), 150µA (medium) and 1000µA (high). This allows the user to trade-off power and AC performance. Recommended bias pin voltages are shown in Table 1-1.

SECTION 2
TTL and CMOS logic based circuits

There are a number of different families of integrated circuits comprising logic gates, which differ in the type and/or connection of the fundamental switching element. The following two are more popular:

- TTL (transistor-transistor logic). It comprises bipolar transistors (npn, pnp)
- MOS (metal-oxide-semiconductor logic). It employs MOSFET transistors (CMOS, PMOS, NMOS)

Each family has different properties characterised by:

(a) ***Noise immunity*** (determined by logic voltage levels)

(b) ***Fan-out*** (determined by current drive, i.e., current sinking and sourcing capability)–the maximum number of gate inputs that can be reliably driven by one output from the same logic family. *Note*. Current sinking means that a device connected between the positive supply and the chip output will be switched on when the chip output is low (0V). Current sourcing means that a device connected between the chip output and the negative supply (0V) will be switched on when the chip output is high.

(c) ***Propagation delay—***the delay between a change in logic level at the input and the corresponding change at the output (may be different for high and low-going signals).

(d) ***Power requirements—***the voltage and current drive required by the circuit.

The TTL and CMOS logic families each have a number of groups (TTL groups include 74xx, 74S, 74LS, 74AS, 74ALS, 74F type devices while CMOS groups include 4000, 74HC, 74AC, 74AHC, 74ALVC, 74AVC and 74ALB type), with each group optimised for a certain function. However, here we shall limit ourselves to 7400 TTL and 4000 series of CMOS devices for a comparison of their properties.

(e) Comparison: The input of CMOS requires very low current and hence uses less power than a TTL gate at moderate clock frequencies. However, at very high clock frequencies (switching rates) the power consumption of a CMOS gate increases to TTL consumption levels.

A TTL gate switches logic levels faster than a CMOS gate does. Therefore you should weigh power savings against switching speed when deciding between a CMOS or TTL gate. Because low power consumption means low heat generation, a CMOS has a higher packing density. Many more gates can be placed per unit of IC area.

CMOS gates have much higher noise immunity than the TTL gates.

TTL gates have a nominal positive supply voltage (V_{CC}) of 5 Vdc (4.5 Vdc to 5.5 Vdc) while the negative supply is ground. On the other hand, CMOS gates have a nominal positive supply voltage (V_{DD}) range of 5 Vdc to 15 Vdc while the negative supply voltage (V_{SS}) is to be less than the input or output voltages.

Trigger levels for TTL and CMOS (4000) gates for toggling their logic states are shown in Fig. 2.1.

Typical propagation delay of a standard TTL gate is

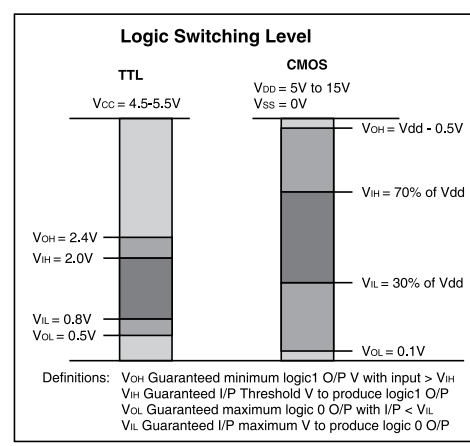

Logic Switching Level
TTL
CMOS
VCC = 4.5-5.5V
VDD = 5V to 15V
VSS = 0V
VOH = Vdd - 0.5V
VIH = 70% of Vdd
VOH = 2.4V
VIH = 2.0V
VIL = 30% of Vdd
VIL = 0.8V
VOL = 0.5V
VOL = 0.1V
Definitions: VOH Guaranteed minimum logic1 O/P V with input > VIH
VIH Guaranteed I/P Threshold V to produce logic1 O/P
VOL Guaranteed maximum logic 0 O/P with I/P < VIL
VIL Guaranteed I/P maximum V to produce logic 0 O/P

Fig. 2.1: Trigger levels for TTL and CMOS (4000) gates

9 ns (nano-second) compared to 25 ns for a 4000 series CMOS gate. This accounts for much lower cut-off frequency for a CMOS gate.

The above basic information will come handy while experimenting with the various TTL and CMOS IC based projects that follow. We shall start with a CMOS quad 2-input NAND gate 4011 IC, as shown in Fig. 2.2 (a).

CD4011 quad 2-input NAND gate: IC CD4011 is a 14-pin DIP (dual in-line pin) package containing four

identical 2-input (and one output) NAND gates. Pin 7 is Vss pin, which may be connected to ground, while V_{DD} (pin 14) is to be connected to any desired voltage between 5V and 15V positive. A truth table is used to interpret the relationship between the logic level present at input pins (call them A and B) and the resulting output logic state of any of its four NAND gates. A NAND gate is special

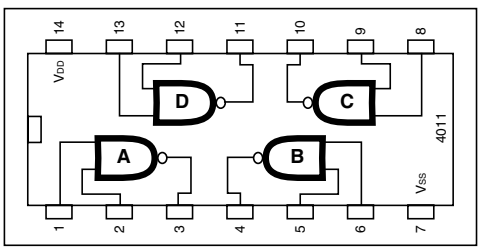


Fig. 2.2 (a): 4011 quad 2-input NAND gate

because you can easily realise the function of other gates using the minimum number of these gates. Here they are:

(a) Inverter or NOT gate. It can be obtained by just shorting both inputs of a NAND gate as shown. The truth table is shown in Fig. 2.3 (a).

Input A	Input B	Output Y
0	0	1
0	1	1
1	0	1
1	1	0

Fig. 2.2 (b): Truth table of a NAND gate

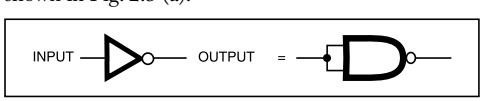


Fig. 2.3 (a): Inverter gate realisation

(b) AND gate: An AND gate can be realised by adding another NAND gate with both inputs shorted as shown.

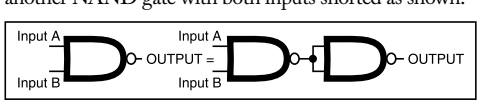


Fig. 2.4 (a): AND gate realisation

(c) OR gate: It is realised by using three NAND gates as shown.

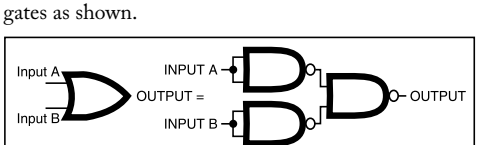


Fig. 2.5 (a): OR gate realisation

Input	Input
0	1
1	0

Fig. 2.3 (b): Inverter Truth table

A	B	Output
0	0	0
0	1	0
1	0	0
1	1	1

Fig. 2.4 (b): AND gate Truth table

A	B	Output
0	0	0
0	1	1
1	0	1
1	1	1

Fig. 2.5 (b): OR gate Truth table

A	B	Output
0	0	1
0	1	0
1	0	0
1	1	0

Fig. 2-6 (b): NOR gate Truth table

(d) NOR gate: It requires an additional NAND gate at the output of OR gate as shown.

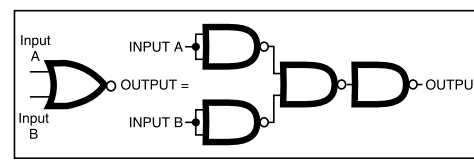


Fig. 2.6 (a): NOR gate realisation

(e) XOR (Exclusive OR): Gate realisation requires use of five NAND gates as shown in Fig. 2.7 (a). Another

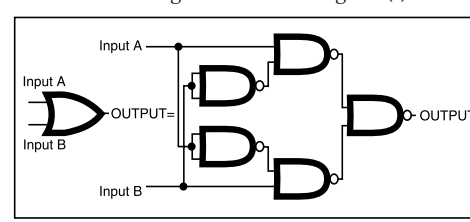


Fig. 2.7 (a): XOR gate realization

NAND gate is required to achieve Exclusive-NOR gate function.

Now we shall experiment with some practical circuits using NAND gate 4011 and a few additional components.

INPUT		XOR Output
A	B	X = A⊕B
0	0	0
0	1	1
1	0	1
1	1	0

Fig. 2.7(b): XOR gate Truth table

NAND gate(s) based circuits

Project 10
A set-reset (bi-stable) flip-flop

When two NOR gates are cross-connected, as shown in the schematic diagram, there will be positive feedback from output to input. That is, the output signal tends to maintain the gate in its last output state. The purpose of the Enable input is to enable or disable the Set and Reset inputs from having an effect over the circuit's output status. When the Enable input is 'low,' the Set and Reset inputs are disabled and have no effect whatsoever on the outputs, leaving the circuit in its latched state.

When the Enable input is 'high' (switch S2 'on'), closing the set switch causes the Q output to go high and light up LED1 (simultaneously, the feedback from output of NAND gate C to input of NAND gate B causes $\overline{Q}$ output to go low to extinguish LED2). On the other hand with Enable switch S2 'on', if Reset switch S3 is closed, the $\overline{Q}$ output goes high, lighting up LED2, while feedback from output pin of NAND gate B to input of NAND gate C causes the Q output to go low and thus extinguish LED1.

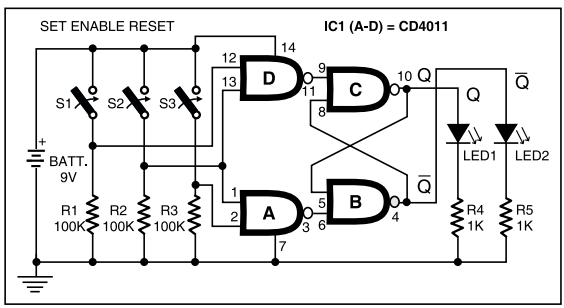


Fig. 2.8: Quad NAND based set-reset (bi-stable) flip-flop

PARTS LIST		
IC1 (A-D)	- CD4011	- quad 2-iput NAND
LED1, LED2	- 5mm LED	- red and blue LEDs
R1, R2, R3	- 100-kilo-ohm	- resistor, 0.25W, 5%
R4, R5	- 1-kilo-ohm	- resistor, 0.25W, 5%
S1, S2, S3	- Switch SPST	- toggle switch
Batt.	PP9	- 9V battery

Project 11
Touch sensitive alarm

In this circuit (Fig. 2.9), NAND gate A is used as high impedance input buffer, while NAND gate D is used as an output buffer/inverter. NAND gates B and C form a monostable with a pulse-width determined by the values of capacitor C1 and resistor R3, with its period T given by equation: T=0.7R3C1.

A momentary touch of the touch plates bridging their gap with a finger causes the input of gate A to go high and its output falls to logic 0 state. This output is connected

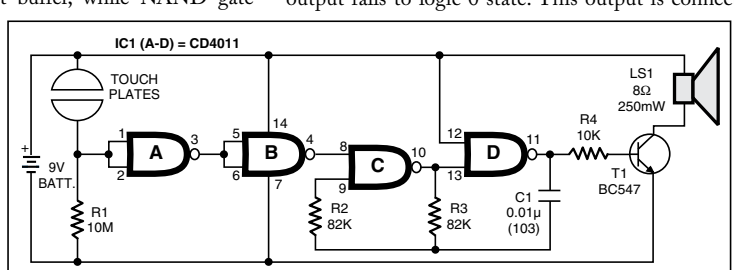


Fig. 2.9: Touch sensitive alarm

PARTS LIST				
IC1	-	CD4011	-	quad 2-input NAND gate
T1	-	BC547	-	npn transistor
R1	-	2.2-mega-ohm	-	resistance, 0.25W
R2	-	10-mega-ohm	-	resistance, 0.25W
R3	-	2.2-kilo-ohm	-	resistance, 0.25W
C1	-	220µF, 25V	-	capacitor, electrolytic
LS1	-	8-ohm, 250mW	-	miniature loudspeaker
Batt.	-	9V battery		
	-	Touch plate pair		

to input pins 5 and 6 of NAND gate B. The output of gate B goes high. At this instant, input of gate C also goes high. As a result, oscillator built around gates C and D starts oscillating and produces a frequency at pin 11 of gate D. The output of gate D is further connected to transistor T1. Transistor T1 is used to drive the miniature loudspeakers. With the given values of R3 and C1, the frequency of sounding of alarm is approximately 535Hz.

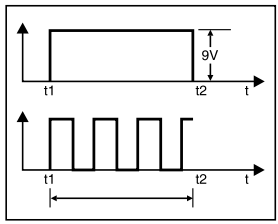


Fig. 2.10: The logic input state of NAND gates A (above) and D (below)

The logic input state of NAND gate A, on bridging the gap of touch plates for a brief period, and the output state of NAND gate D are shown in Fig. 2.10.

Project 12
On/off ringer

This circuit (Fig. 2.11) produces an audio tone of around 450 Hz interrupted at the rate of around 1.2 Hz. With switch S1 open, the first section comprising NAND gates A and B, together with resistors R1, R2 and capacitor C1, oscillates at around 1.2Hz frequency as determined by the following equation:

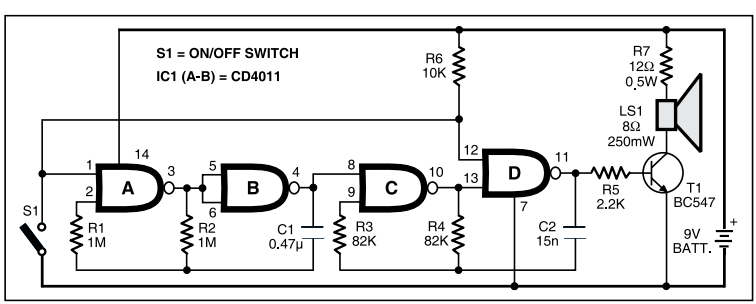


Fig. 2.11: On/off ringer circuit

Frequency (Hz)=0.56/RC, where R1=R2=R and C1 =C

Similarly, when pin 4/pin 8 (shorted) are at logic 1, the oscillator comprising NAND gates C and D and the components around it, oscillate at a frequency of around 450 Hz. Since NAND gate C is enabled for around 0.6 seconds and inhibited for same period, the 450 Hz output from the second section is interrupted accordingly. The output from the second section is used to drive the miniature loudspeaker LS1 via amplifier transistor T1.

Thus, as long as switch S1 is open, we hear the 450Hz on/off tone from the loudspeaker, and when switch S1 is closed, NAND gates A and D are disabled. Hence the oscillators are de-activated and no tone is heard. In place of switch S1, we can control the operation of ringer remotely through a micocontroller or another logic circuit, if desired.

PARTS LIST				
IC1	-	CD4011	-	quad 2-input NAND gate
T1	-	BC547	-	npn transistor
R1, R2	-	1-mega-ohm	-	resistor, 0.25W
R3, R4	-	82-kilo-ohm	-	resistor, 0.25W
R5	-	2.2-kilo-ohm	-	resistor, 0.25W
R6	-	10-kilo-ohm	-	resistor, 0.25W
R7	-	12-ohm	-	resistor, 0.5W
C1	-	0.47µF	-	capacitor, polyester
C2	-	15nF	-	capacitor, polyester
S1	-	SPST	-	toggle switch
LS1	-	250mW, 8-ohm	-	miniature loudspeaker
Batt.	-	9V	-	battery

Project 13
Toilet 'busy' indicator

Restaurants, theatres, bus stations, railway stations, etc are places where public toilets are used. Usually, there is no way of knowing whether a toilet is occupied or vacant. The only alternative is to knock on the door and find out.

This simple circuit (Fig. 2.12) displays the 'busy' by the inside bolt of the toilet door, such that when the bolt is engaged (locked), the switch terminals get shorted. This happens when a person is inside the toilet and is using it. The engagement of the bolt causing the micro switch to close results in the input pin 1 to go high, to enable NAND gate A, and the oscillator starts functioning.

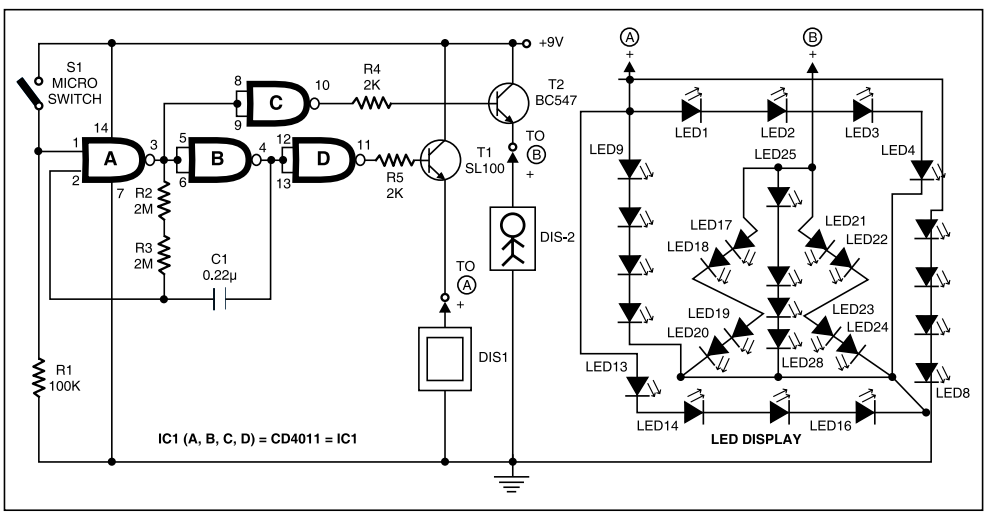


Fig. 2.12: Toilet 'busy' indicator circuit including physical arrangement of LEDs

status by lighting up two sets of LEDs mimicking that a human being is inside, to indicate its occupancy, and when the toilet is unoccupied, it lights only one of the two sets of LEDs arranged in rectangular fashion.

All four CMOS NAND gates (A through D) from quad NAND gates of IC CD4011 are used in the circuit. The first two NAND gates (A and B) are wired as an oscillator (clock pulse generator), while NAND gates C and D act as buffer/ inverters. In its quiescent state (i.e., when the toilet is vacant and switch S1 is open), pin 1 of gate A is at logic 0 level through resistance R1. This inhibits the oscillator circuit and sets the output of gate A at logic 1 (high) state; this output after double inversion by NAND gates B and D is still high. As a result, transistor T1 conducts and the set of LEDs (annotated DIS-1) is illuminated continuously to indicate that the toilet is vacant.

S1 is a micro-switch, which is mechanically operated

PARTS LIST		
IC1	- CD4011	- quad 2-input NAND gate
T1	- SL100	- npn transistor
T2	- BC547	- npn transistor
DIS-1	- LED1-LED16	- green, 5mm flat (16 Nos.)
DIS-2	- LED17-LED25	- red, 5mm round (12 Nos.)
R1	- 100-kilo-ohm	- resistor, 0.25W
R2, R3	- 2-mega-ohm	- resistor, 0.25W
R4, R5	- 2-kilo-ohm	- resistor, 0.25W
C1	- 0.22µF	- capacitor, polyester
S1	- SPST/SPDT	- micro switch

Now, both sets of LED displays (connected as DIS-1 and DIS-2) are illuminated alternately, indicating that the toilet is occupied.

Suggestion. Use green LEDs for LEDs connected in rectangular fashion as DIS-1, while for DIS-2 you may use red LEDs to depict a person within the green rectangle.

Project 14
Electronic direction pointer

Many a times we use a pointer to point out a particular direction. For example, to show the way to an exit or toilet or a staircase. Here is a circuit of an electronic illuminated direction pointer, which is more eye catching than any ordinary pointer.

The circuit employs a quad 2-input NAND gate IC CD4011 and a few other components. There are four sets (segments) of LEDs arranged in the form of an arrow, and LEDs forming part of a segment of the arrow are lit up simultaneously. All the NAND gates are connected as inverters (N1, N2, N3 and N4). Resistor-capacitor combinations of R1-C1, R2-C2, R3-C3 constitute delay networks (delay ≈ R1C1=R2C2=R3C3 seconds), which ensure that outputs of N1, N2 and N3 take finite time to travel to the input of the gates that follow.

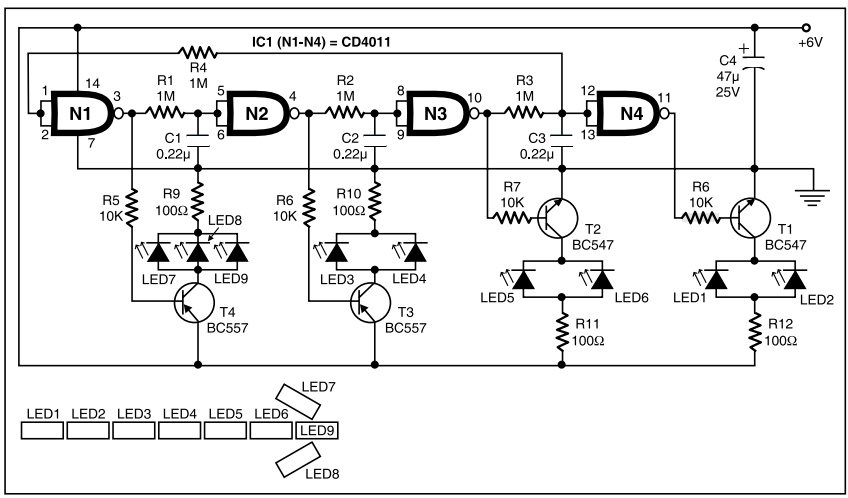


Fig. 2.13: Electronic direction pointer circuit

When power is switched on, the inputs to the inverters N1 and N4 (interconnected through resistance R4) are at logic0 level (as capacitors act as short initially) and their outputs are at high logic level. The high logic level at the output of N4 provides the npn type silicon transistor T1 with its base current and it drives LEDs 1 and 2, and they glow.

Similarly, the high logic level at the output of N1 makes the input of N2 high. There is a certain delay in this process due to the presence of resistor R1 and capacitor C1 at the input of N2. High logic level at the input of N2 makes its output low and transistor T3 is activated; hence, LEDs 3 and 4 glow. In the same manner, input of N3 goes low after some delay due to R2 and C2, and its output goes high. So transistor T2 is activated and LEDs 5 and 6 glow. Finally, the high logic level at the output of N3 makes the input of N1 high, and so its output is low. Thus, T4 is activated and LEDs 7, 8 and 9 glow.

In this way, the four sets of LEDs are lit up one after another and the cycle is repeated. The arrangement of LEDs in the shape of an arrow is shown in the figure. To slow down the speed of the glowing LEDs, you may increase the values of R1, R2, R3 and C1, C2, C3. However, R1, R2 and R3 must have equal values and C1, C2 and C3 should also have equal values to maintain identical delay between switching of each segment.

PARTS LIST		
IC1	- CD4011	- quad 2-input NAND
T1, T2	- BC547	- npn transistor
T3, T4	- BC557	- pnp transistor
LED1-LED9	- LED	- 5mm red flat LED
R1-R4	- 1-meg-ohm	- resistor, 0.25W
R5-R8	- 10-kilo-ohm	- resistor, 0.25W
R9-R12	- 100-ohm	- resistor, 0.25W
C1-C3	- 0.22µF	- capacitor, polyester
C4	- 47µF, 25V	- capacitor, electrolytic
Batt.	- 6V	- battery

Project 15
Simple soil moisture level controller

The circuit presented here is that of a low-cost and simple soil moisture controller. It switches on the sprayer pump, through the N/O (normally open) contacts of a relay when the moisture level is inadequate for the growth of plants, and switches off when the moisture level comes to a preset level.

In the circuit of the moisture controller, both inputs of both the NAND gates are shorted together and act as simple inverters. The moisture level is sensed by a pair of metallic probes, which are embedded in the soil to a suitable depth and separation from each other. When soil has inadequate moisture, the soil resistance is pretty high, so both inputs of NAND gate N1 become high and its output goes low. The low output of N1 is coupled to gate N2 and its output goes high. The high output of gate N2 forward biases transistor T1, which starts conducting and turns the pump on through the relay contacts.

Once the moisture level reaches a preset level, the output of gate N2 becomes low. As a result, transistor T1 stops conducting and the relay de-energises to stop the pump. The process repeats when the moisture level drops below the preset level.

PARTS LIST		
IC1	- CD4011	- quad 2-input NAND
T1	- BC148/BC548	- npn transistor
D1	- 1N4001	- rectifier diode
R1	- 33-kio-ohm	- resistor, 0.25W
R2	- 10-kio-ohm	- resistor, 0.25W
RL1	- 9V, 1 C/O	- 1A (contact rating)
Batt.	- 9V	- battery
	- Probe pair	- long nails may be used

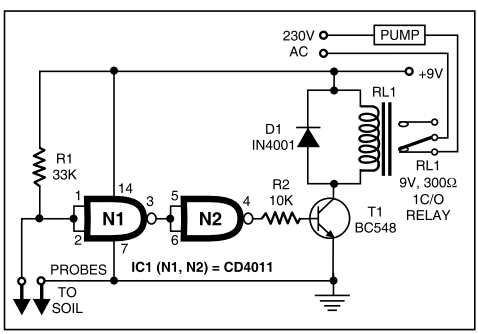


Fig. 2.14: Soil moisture level controller circuit

Project 16
Touch-sensitive single-chip flasher-cum-beeper

The circuit of an inexpensive, compact, touch-controlled flasher-cum-beeper is shown in Fig. 2.15.

The circuit can be divided into two parts, namely, an RS flip-flop comprising NAND gates N1 and N2, and flashing an LED oscillator section comprising NAND gates N3 and N4. The frequency of oscillation, which causes flashing of an LED and beeping of a piezo-buzzer, is determined by the in-circuit resistance value of preset VR1 and capacitor C3.

When touch plate TP1 is bridged with a fingertip, the output of gate N1 goes high and enables the beeper-cum-flasher section. When touch plate TP2 is bridged with a fingertip, the output of N1 goes low and

PARTS LIST		
IC1	- CD4011	- quad 2-input NAND
D1	- LED	- 5mm
R1, R2	- 5.6-mega-ohm	- resistor, 0.25W
R3-R5	- 220-kilo-ohm	- resistor, 0.25W
R6	- 1-kilo-ohm	- resistor, 0.25W
VR1	- 1-mega-ohm	- preset
C1, C2	- 6.8nF	- capacitor, ceramic disk
C3	- 1µF, 16V	- capacitor, electrolytic
	- Buzzer	- piezo buzzer
TP1, TP2	- Probe	- metal plates

inhibits the oscillator, and as a result flasher-cum-beeper is disabled. Capacitors C1 and C2 across TP1 and TP2 have been used to avoid false triggering due to electrical noise. If the circuit is desired to be used only as a flasher or only as a beeper, we may do away with the LED or the buzzer, as the case may be.

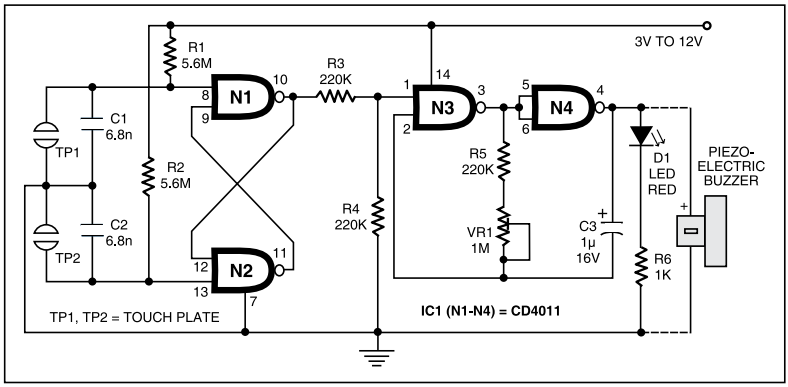


Fig. 2.15: Touch-sensitive single-chip flasher-cum-beeper

Project 17
Automatic water pump controller

The circuit of a water pump controller, as shown in Fig. 2.16, comprises three npn transistors, all connected as emitter followers to present high input and low output impedance. Gate N1 of the quad NAND

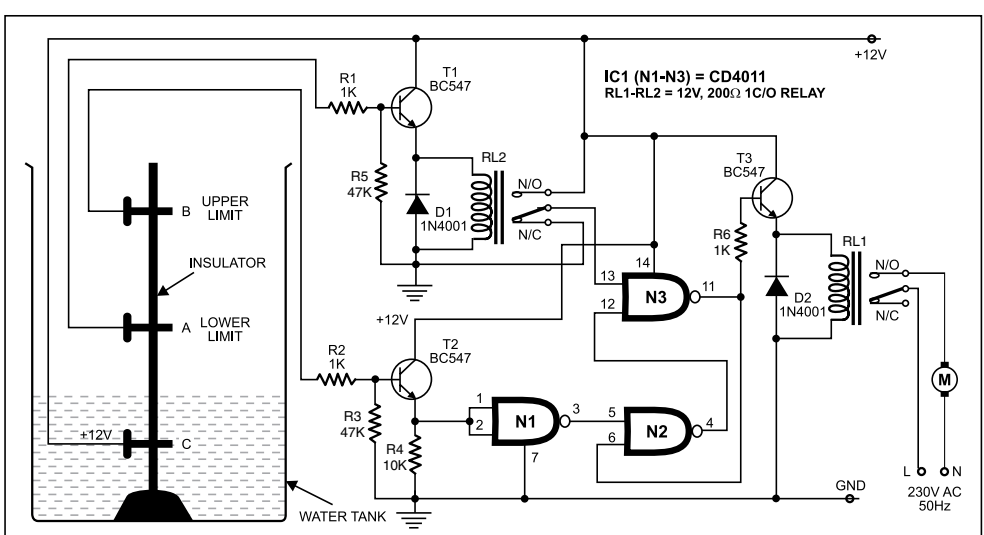


Fig. 2.16: Automatic water pump controller circuit

gate IC is connected as an inverter, while two other NAND gates N2 and N4 form a set-reset flip-flop controlled by outputs of NAND gate N1 and pole voltage of relay RL2. The tank has a reference probe C, which is directly connected to 12V supply, while probe A represents the lower limit of liquid (any conductive liquid including normal drinking water) level. If liquid level falls below this level the pump motor must start and remain on until the liquid touches the upper probe B. When the liquid level falls below probe A level, transistor T1 is cut off and hence pin 13 of gate N4 (via N/C contact of relay RL2) is at ground level. The output pin 11 of gate A therefore goes high. Transistor T3 conducts to energise relay RL1 and the pump motor is switched on through its contacts. Once water touches probe A (but not the upper limit probe B), relay RL2 energises because of forward biasing of transistor T1, whereby pin 13 of gate N4 goes high. But its other input pin 12 is low as transistor T2 is not conducting. Hence input to gate N1 is low and the logic output of gate N2 is low.

PARTS LIST		
IC1	- CD4011	- quad 2-input NAND gate
T1- T3	- BC547	- npn transistor
D1, D2	- 1N4001	- rectifier diode
R1, R2, R6	- 1-kilo-ohm	- resistor, 0.25W
R3, R5	- 47-kilo-ohm	- resistor, 0.25W
R4	- 10-kilo-ohm	- resistor, 0.25W
RL1, RL2	- 12V, 1 C/O	- relay with 1A contact rating
	- Probes	- 3 metal probes on insulating rod
	- 12 V battery	

Thus T3 continues to conduct and the motor does not stop. But once the liquid level touches probe B, the output of gate N1 goes low, while output of gate N2 goes high. This causes both inputs of gate N4 to go high and its output pin 11 goes low to cut-off transistor T3. Thus, relay RL1 de-enrgises to switch off the pump motor. Now, even if the water level drops but does not go below probe A level, both inputs to gate N4 continue to remain high and the pump motor remains off. Only when the liquid level goes below probe A level does the cycle repeat itself.

Project 18
Generating three tones using a single digital IC

A low component count, three-tone generating circuit can be constructed using an inexpensive digital IC and a handful of components. It is capable of generating three tones corresponding to the two logic levels at its two inputs. The circuit as shown in Fig. 2.17, is very useful as a source for generating three different tones while transmitting data, e.g., for telemetry and remote control, etc. It uses NAND CD4011 (original circuit used IC 7400 with 5V supply) and a few resistors, diodes and capacitors.

The circuit's output may be connected to a power amplifier for feeding speakers/headphones or transferred through telephone wires to a remote location for further processing. The truth table for different logic level inputs is given here.

The circuit basically functions as an oscillator with the frequencies decided by capacitors C1

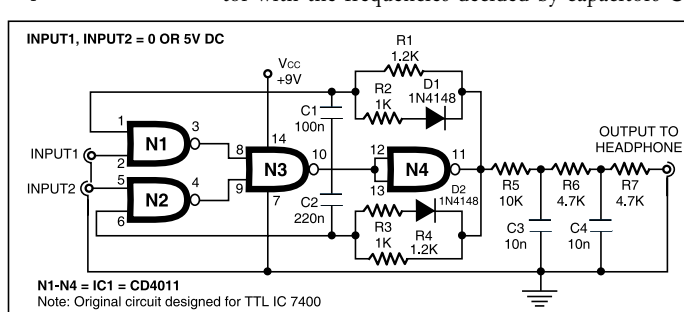


Fig. 2.17: Circuit for generating three tones using a single digital IC

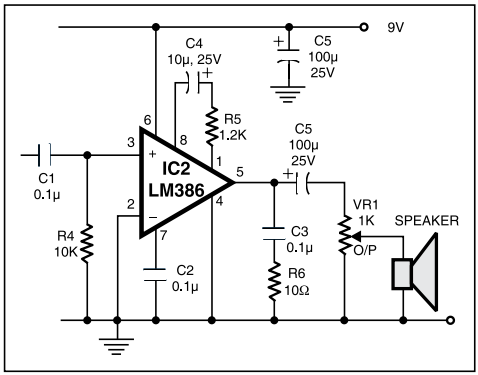


Fig. 2.18: Audio amplifier

and C2, and resistors R1 and R4. Diodes D1 and D2, along with the associated 1k resistors, help to produce 50 per cent duty cycle. These can be done away with if 50 per cent duty cycle is not required. For generating lower frequencies, use higher values for capacitors C1 and C2. Output filters comprising resistors R5, R6 and R7, and capacitors C3 and C4, are necessary to remove the harmonics.

Note: The Fig. 2.18 is an additional circuit from Project 6, which should be connected at the output of Fig. 2.17 into its input (between C1 and ground) for amplifying the output and hearing it through the loudspeaker. (For details, refer Project 6)

Truth Table

Input1	Input2	Tone Generated
0	0	No Tone
0	1	1.2kHz
1	0	2.8kHz
1	1	2kHz

PARTS LIST

IC1	- CD4011	- quad 2-input NAND
D1, D2	- 1N4148	- switching diode
R1, R3	- 1.2-kilo-ohm	- resistor, 0.25W
R2, R4	- 1-kilo-ohm	- resistor, 0.25W
R5	- 10-kilo-ohm	- resistor, 0.25W
R6, R7	- 4.7-kilo-ohm	- resistor, 0.25W
C1	- 100nF	- capacitor, ceramic disk
C2	- 220µF	- capacitor, ceramic disk
C3, C4	- 10nF	- capacitor, ceramic disk

SECTION 3
Timers and Counters

A common requirement in digital circuits is counting, both forward (up-counting) and backward (down counting). Apart from obvious use of timers/counters in digital clocks and watches, timers are found in a range of appliances—from microwave ovens to VCRs. Counters are found in almost everything, ranging from automobiles to test equipment.

There are a host of digital (CMOS and TTL) ICs, which can be used in timer and counter circuits. The CMOS versions include CD4020, CD4040, CD4060, CD4510, CD40102B, CD40110, CD4026, CD4033, CD74HC190, CD74HC192, CD74HC390, CD74HC4017, CD74HC4017, CD74HCT390, CD-74HCT303 etc. LSI (large-scale-integration) ICs like ICM7208, which combine counter and 7-digit display drivers are also available. Besides, counter and timer circuits based on the 555 IC and its variants (e.g., LM555, NE555, SE555 and ICM7555) are very popular. It is neither necessary nor desirable to describe all the listed ICs here. We shall therefore choose the more commonly used timer/counter ICs like 555, CD4017 and CD4026 (CD4033), and describe them in some detail before presenting the application circuits.

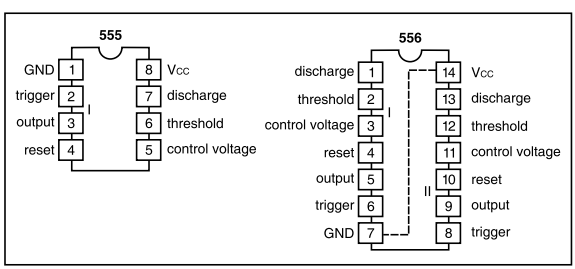


Fig. 3.1: Configuration of 555 and 556 timer ICs.

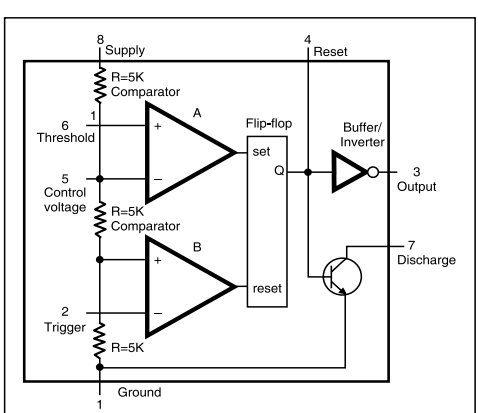


Fig. 3.2: Functional block diagram of 555/556 (one section)

(a) 555 timer and 556 dual timer: A 555 IC (prefix LM, SE etc not used here) is known as a real workhorse IC employed for numerous applications, while 556 comprises two identical similar timers. Their pinouts and signal names are shown in Fig.3.1.

A functional block diagram of 555 timer is shown in Fig. 3.2. It operates over supply voltages that range from 5V to 15V. The two more frequently used modes of its operation are: (a) the monostable mode, and (b) the astable or free running mode.

Monostable mode: A functional diagram of monostable operation is shown in Fig. 3.3. In this mode, a pulse of specific duration appears at the output. This mode is achieved by:

(a) Shorting pins 6 and 7.

(b) Connecting a resistance R between Vcc (pin 8) and junction of pin 6 and 7.

(c) Connecting a capacitor C between junction of pin 6 and 7 (+ve) and ground pin 1 (-ve).

(d) Keeping reset pin high during output pulse period (if taken low at any time during the appearance of output pulse at pin 3, the output pulse will terminate).

(e) Applying a negative trigger which takes pin 2 below 1/3 Vcc level even momentarily. Holding pin 2 below 1/3 Vcc longer, during the pulse period, has no effect. However, if it is held low for a longer period, the output will remain high for the period trigger pin 2 is held low.

(f) Pin 1 may be connected to ground through a 0.01µF capacitor for stable operation.

The output pulse period $\Delta t \approx 1.1RC$ seconds, where R is in ohms and C is in Farads.

Astable mode: Astable connections are shown in Fig. 3.4. The flip flop will produce continuous rectangular

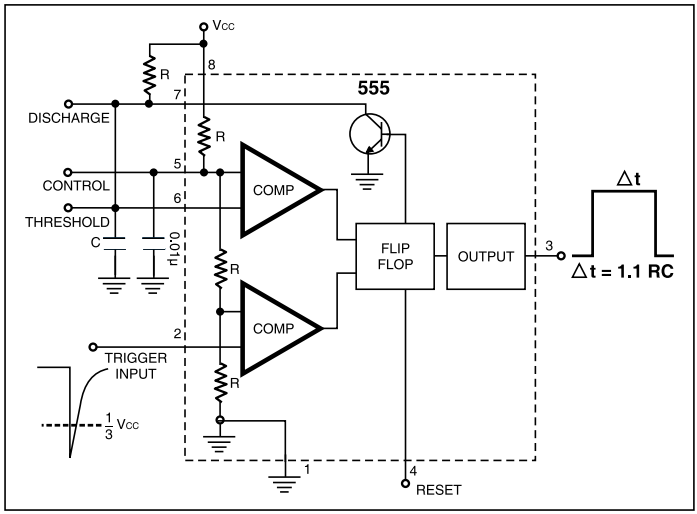


Fig. 3.3: Monostable operation configuration of 555

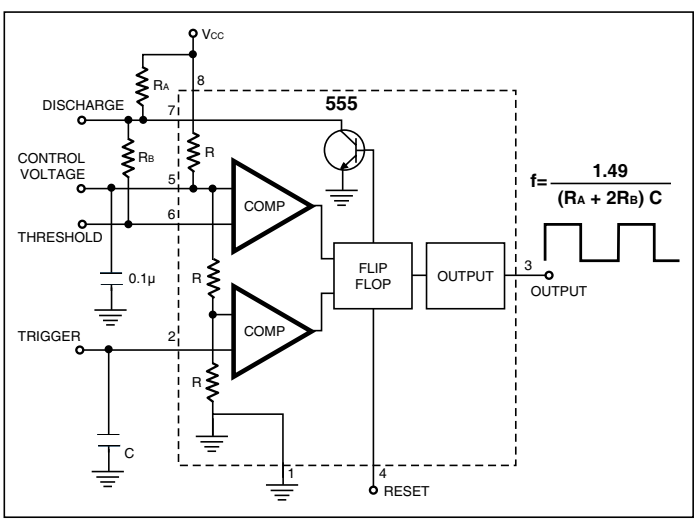


Fig. 3.4: Astable operational configuration of 555

pulses at a frequency f given by the equation:

$$f = \frac{1.49}{(R_A + 2R_B)C}$$

where f is in Hz (cycles per second), resistors R_A, R_B and capacitor C (shown in Fig. 3.4) are in ohms and farads respectively. A complete period comprising positive (mark) and negative (space) t is given by equation:

$t = 0.7 (R_A+2R_B) C$ while positive (Hi) and negative (Lo) periods are given by equations:

$Hi = 0.7 (R_A+R_A) C$ and $Lo = 0.7 (R_B) C$, respectively. The duty cycle {ratio of Hi period to complete (Hi+Lo) period} is given by the ratio $(R_A+R_B)/(R_A+2 R_B)$.

Various parameters of 555 IC, their symbols and test conditions are tabulated in Table 3.1. Practical high frequency limit is around 50kHz, while low frequency limit is rather low as the time period of even few minutes can be realised using low-loss, high-value capacitors.

(b) CD4017 counter: This is a decade counter CMOS IC. The pin configuration is given in Fig. 3.5. For normal operation, V_{DD} pin 16 is connected to a supply between +6 and +15V with Vss pin 8 grounded (negative supply rail). The disable input pin 13 should be low (0V) for normal operation. When the pin is high, it disables counting so that clock pulses are ignored and the count is kept constant. Similarly, the reset input pin 15 should be low (0V) for normal operation (counting 0-9). When reset pin 15 is taken high, it resets the count to zero (Q0 goes high-initial condition).

The count advanc-

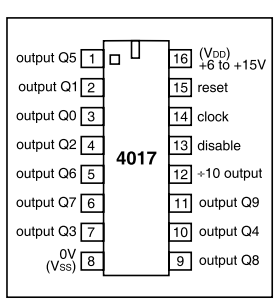


Fig. 3.5: Pin signals of CD4017

TABLE 3-1
Parameters of 555

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Units
V_{CC}	Supply voltage	RA = 2k to 100k; C=0.1μF	4.5		16	V
I_{CC}	Supply current	RA, RB=1k to 100k; C=0.1		10	15	mA
I_{OUT}	Output current	μF; Vcc=15V			200	mA
F_{MAX}	Operating frequency				500	kHz
P_D	Maximum power dissipation				600	mW
T_A	Operating ambient temperature range		0		70	^{0}C
t_M	Timing error in monostable mode			1,0	3,0	%
t_A	Timing error in astable mode			5	13	%
V_{cl}, V_{th}, V_{mg}, V_{reset}	All input voltages				Vcc	V

during 5-9 time intervals of the clock. When the counter counts through its full range, a square wave at f/10 and 50% duty cycle appears at this output, where f is the clock frequency. This output can be used as the clock for another counter that gives an additional divide by 10. This output should not be equated with 'terminal count' or TC, which normally occurs on the tenth count in a decade counter. This output can be used to drive the clock input of another 4017 (to count es as the clock input goes high (on the rising-edge). Each output Q0-Q9 goes high in turn as the counting/clock advances. For some functions (such as flash sequences), outputs may be combined using diodes.

Counting to less than 9 is achieved by connecting the relevant (one out-of-ten) outputs (Q0-Q9) to reset pin 15. For example, to count 0, 1, 2, 3 connect the next output (Q4) to reset pin 15. The output pin (÷ by 10), misnamed Carry Out or CO, is not a carry output, but is the output of the fifth flip-flop in the counter. It is low during the 0-4 time intervals, and is high

TABLE 3-2
Pin functions of CD4017

Pin number	Name	Purpose
1 through 7, 9 through 11	Output pins	Sequential outputs appear at pins 3, 2, 4,7, 10, 1, 5, 6, 9 and 11–in this order
12	CO	Carry out output - outputs high on counts 0 to 4, outputs low on counts 5 to 9 (thus a transition from low to high occurs when counting from 9 back to 0)
13	LE	Latch enable-latches on the current output when high (i.e., the chip counts when LE is low)
14	CLK	Clock in
15	RST	Reset-sets output 1 high and outputs 2 through 10 low, when taken high
16	+9V, VCC	The connection to the +VCC rail (voltage between +3V and +15V)
8	0V, VDD	The connection to the 0V rail

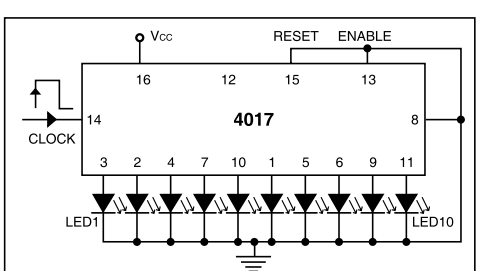


Fig. 3.6: Sequential LED lights using CD4017

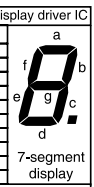
the tens). A typical connection diagram with external clock input, which sequentially switches on ten LEDs cyclically, is shown in Fig. 3.6. Pin functions are shown in Table 3-2.

(c) CD4026B and CD4033B counters: Both consist of a 5-stage Johnson decade counter and an output decoder which converts the Johnson code to a 7-segment decoded output for driving one digit of a 7-segment common-cathode display. Fig. 3.7 shows the decoded segment outputs for all counts (0 through 9). A high Reset signal clears the decade counter to its zero count. The counter is advanced one count at the positive transition of the clock, provided the Clock Inhibit signal input pin is low. The Carry-Out (C_{OUT}) signal at pin

Output from the 4026 counter and display driver IC

Count	a	b	c	d	e	f	g	h
0	●	●	●	●	●	●		●
1		●	●					●
2	●	●		●	●		●	●
3	●	●	●	●			●	●
4		●	●			●	●	●
5	●		●	●		●	●	
6	●		●	●	●	●	●	
7	●	●	●					●
8	●	●	●	●	●	●	●	●
9	●	●	●	●		●	●	●

● = segment on. h is used to drive other counters.



7-segment display

Fig. 3.7: CD4026 decoded segment outputs for counts 0 through 9

5 completes one cycle every ten Clock Input cycles, and is used as a clock for the succeeding decade counter in a multi-decade counting chain. Pin functions of CD4026 and CD4033 are shown in Fig. 3.8. Pin functions of CD4026 are given in Table 3-3.

There are some minor differences between the CD4026 and CD4033 ICs. These pertain to different functions of pins 3, 4 and 14. The CD4033 has a provision for automatic blanking of the non-significant zeros in a multi-digit decimal number, which results in an easily readable display consistent with normal writing practice. For example, a number 030.070 in a 3-digit display would appear as 30.07, which is quite logical. To achieve this, you have to connect RBI (ripple blanking input) pin3 of the most significant digit (first from left-hand-side CD4033 in 6 cascaded stages) to a low level, and its RBO (ripple blanking output) pin 4 of the most significant digit to RBI pin of the next lesser significant digit. This procedure is continued for each succeeding CD4033 stage on the integer side of the display.

On the fraction side of the display, the RBI pin of the CD4033 associated with the least significant bit is connected to a low-level voltage, and its RBO pin is connected to the RBI pin of the next higher-significant-bit position. Again, this procedure is continued for all stages on the fraction side of the display.

Further, CD4033 has a Lamp Test input which, when connected to a high-level voltage, overrides normal decoder operation and enables a check to be made on possible display malfunctions by putting the seven outputs in the high state.

TABLE 3-3
Pin functions of CD4026

Pin number	Purpose
1	Clock in
2	Clock inhibit - when low, clock pulses increment the seven-segment
3	Display enable - the chip outputs to the seven-segment when this is high (i.e., when it's low, the seven-segment is off) - useful to conserve battery life, for instance
4	Display enable out - for chaining 4026s
5	Carry out output - Is high when changing from 9 to 0. It provides an output at 1/10 of the clock frequency, to drive the clock input of another 4026 to provide multi-digit counting.
6, 7 and 9 through 13	Output for the seven-segment's in the order: pin 6=F, 7=G, 9=D, 10=A, 11=E, 12=B and 13=C
14	Ungated C-segment - an output for the seven-segment's C input, which isn't affected by the DE input. This output is high unless the count is 2, when it goes low.
15	Reset-resets all outputs to low when taken high
16	The connection to the +9V rail
8	The connection to the 0V rail

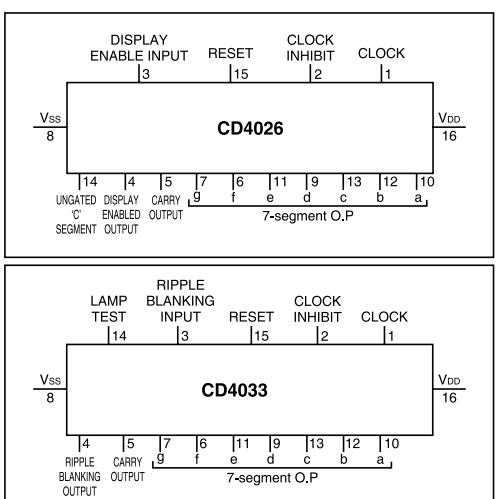


Fig. 3.8: Pin functions of CD4026 and CD4033

Timer and Counter based circuits

Project 19
Divide-by-N counter using CD4033

We generally use IC 4033 for counting. It is a decade counter/decoder/7-segment LED display driver. But on several occasions we need less than a divide-by-10 counter. For example, in a digital clock, in the minutes position, the digital die must count only up to number 6, the tens digit of minutes. In fact, it should show no more than number 5, and the tens digit of the hour counter should not reach higher than number 11 in 12-hour mode and 23 in 24-hour mode. But no such facility of division by a number less than 10 is directly available in 1C 4033. We may, however, achieve it by decoding the segment driving outputs of IC using gates and flip-flops to reset it on reaching the desired count.

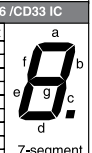
The operation of divide-by-n counters will now be explained with the help of Tables 3-4, 3-5 and Figs. 3.9 through 3.11.

Project 19A
Divide-by-2 through 6 and 8

Starting with division by 2 requires that the counter should be reset (to zero) on every second pulse. The display would thus indicate 0 and 1 only. To reset the counter, a positive pulse has to be applied to reset pin 15 on the start of the second count, and it should be low during the first count. An analysis of Table 3-4 indicates that the output for segment 'g' is low during count 0 and 1, and high at count 2. This will meet our requirement for resetting the counter. So the output for segment 'g' (pin 7) is required to be connected to pin 15. This is achieved by flipping switch S7 to 'on' position (as indicated in Table 3-5), while other switches S2 through S6 are kept off. The resetting action is very fast and one cannot see number 2. The reset pin is normally connected to the positive rails via a resistor R4 (100k) and common anode point of the diodes (D1 through D6), whichever is/are selected via switches S2 through S7 (parts of 6-way DIP switch) are shown in Fig. 3.9.

TABLE 3-4
Segment outputs usage

Segment output from the CD4026 /CD33 IC								
Count	a	b	c	d	e	f	g	Cout
0	●	●	●	●	●	●		●
1		●	●					●
2	●	●		●	●		●	●
3	●	●	○	●			●	●
4		●	●			●	●	●
5	●		●	○		●	●	
6	●		●	●	○	○	○	
7	●	○	●					
8	●	○	●	●	○	○	○	
9	○	○	●	●	○	○	○	



7-segment display

● = segment on. - Off Count=carry output
○ Black ring indicates outputs (in a row) used for division by number shown under column 'count'.

TABLE 3-5
Switch operation

Divide by	Switches to be on (all other switches off)
2	S7
3	S7, S3
4	S7, S6
5	S7, S6, S4
6	S7, S6, S5
8	S7, S6, S5, S2

Lamp test pin 14 is normally grounded via resistor R2 (100k). When reset switch S1 is pressed, all segment outputs, including segment 'g', go logic high. As a result, pin 15 goes high

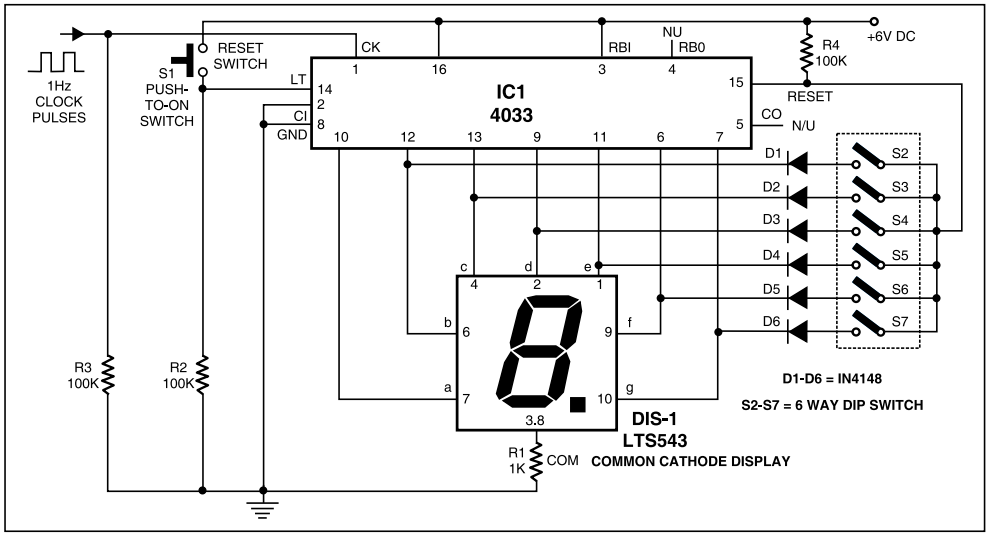


Fig. 3.9: Divide-by-2 through 6 and 8 counter circuit

and the counter is reset. For achieving a divide-by-3 counter, the circuit must count 1, 2, and on the third count it should reset to zero. Since we cannot connect 'g' segment output alone, we select two segment outputs such that both are high during third count and low (at least one of them) during 0, 1 and 2 count. By inspecting Table 3-4, we may select segment outputs 'c' and 'g' which meet the above-mentioned condition.

These outputs are to be ANDed and applied to reset pin 15. The ANDing via diodes results in a voltage drop of approximately 0.6V during count operation, i.e., when at least one of the diodes is not blocked, as explained earlier. Similarly, division by 4, 5, 6 and 8 is achieved by ANDing the requisite segment outputs as shown in Table 3-4 with the help of switches S2 through S7. Since the diodes (D1-D6) are all in the blocking state when pin 14 (LT) is logic high, pressing switch S1 always leads to resetting of the counter in any of the above-mentioned division operations.

Common Parts list for projects 21A through 21C

IC1-IC3	- CD4033	- decade counter/
		- 7-segment display driver
D1-D9	- 1N4148	- switching diode
T1	- BC547	- npn transistor
DIS1-DIS3	- LT543	- 7-segment common cathode display
S1, S8, S9		- tactile switch (push-to-on)
S2-S7		- 6-way DIP switch
R1, R6, R10	- 1-kilo-ohm	- resistor, 0.25W
R2-R5, R7-R9		
R11, R12	- 100-kilo-ohm	- resistor, 0.25W
C1	- 1nF	- ceramic disk

Project 19B
Divide-by-7 counter

From Table 3-4, as given in Project 19-A, it is observed that three outputs pertaining to segment 'a', 'b' and 'c' are high on the seventh count. All these outputs are also high during the reset state, i.e., during the number '0' as well as number '3'. To bring the reset pin high during the reset and number '3' count, other segment outputs,

i.e., 'd', 'e', 'f', and 'g' cannot be used as we did previously, since these outputs are low for seventh count (number 7), and hence the resetting cannot occur. To overcome this situation, a sharp pulse is applied to the reset pin on the seventh count. Table 3-4 reveals that segment 'b' output using differentiator circuit formed by capacitor C1 and resistor R7. During fifth and sixth counts, the segment 'b' output is low, and during this period capacitor C1 discharges via the internal resistor of IC2 and resistor R5, and thus is ready to produce a sharp pulse at seventh count during the next cycle. Pin LT (14) cannot be used to reset the counter in this case because, up to the fourth count, the segment 'b' output is high and, as a result, capacitor C1 is in the charged condition and cannot produce a sharp pulse when we need to reset the counter during these phases. So reset switch is connected to reset pin 15 as shown in Fig. 3.10. Parts list is the same as given in Project 19A.

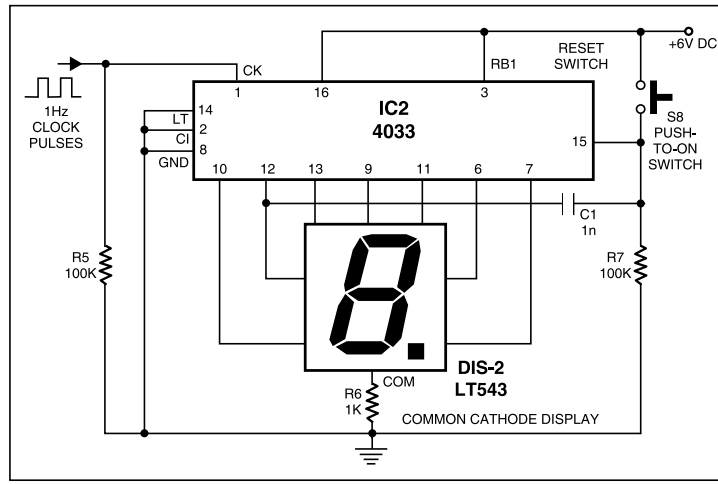


Fig. 3.10: Divide-by-7 counter circuit using CD4033.

Project 19C
Divide-by-9 counter

No segment output can be used in this case because all segment outputs are high on the eighth count. Pulse method used for divide-by-7 circuit cannot be used in this case. Here, segment 'e' output (pin 11) is inverted using transistor T1. The inverted output, along with the outputs of segments 'a', 'b' and 'f' are ANDed by diodes D7 through D9 and used to obtain divide-by-9 counter. The counter resets on the ninth count. Parts list is same as given in Project 19A.

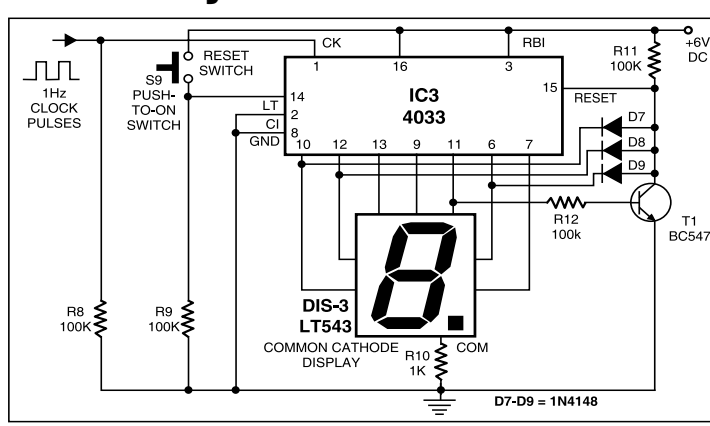


Fig. 3.11: Divide-by-9 counter using CD4033.

Project 20
Divide-by-N counter realisation using 555, CD4033 and CD4017

On several occasions, a less than divide-by-10 counter is needed, which cannot be configured using CD4033 (or CD 4026) alone. In the circuit shown here, another decade counter IC CD4017 has been used with CD4033 to realise such a counter/divider by using the selected output of IC CD4017 to reset both the ICs after a predetermined count.

Timer IC1 (555) is configured as an astable oscillator as an input clock/frequency source feeding the clock input to both the counters (CD4017 and CD4033). Any other external digital clock source, whose frequency is to be divided by n (where n is any digit between 1 and 9), can be connected in place of IC1.

Depending upon the position of the rotary switch, one can select division by any integer less than 10. If one wants to use the circuit as a divide-by-2 counter, the pole of the rotary switch should be kept on Q2 output of IC2. The display would advance from 0 to 1 on the first low-to-high transition of the input clock. On the second clock (low-to-high) transition, the Q2 output would go high momentarily and reset both IC2 and IC3. As a result, the display would not be able to show number 2 for a perceptible period. Hence, the maximum number displayed appears to be one less than the selected division factor.

The Q output from CD4017 (IC2) as available at the pole of rotary switch S1 is input to monostable IC4 (NE555) to provide proper pulse-width (output) for resetting IC2 as well as IC3. In Q0 position of the rotary switch, both IC2 and IC3 counters remain permanently reset and the display shows 0 all the time. When we select division-by-1, the counter will still show 0 only, as per the logic explained earlier.

PARTS LIST

IC1, IC4	- NE555	- timer
IC2	- CD4017	- decade counter
IC3	- CD4033	- decade counter, 7-segment display driver
DIS1	- LT543	- 7-segment LED display (CC)
R1, R4	- 1-kilo-ohm	- resistor, 0.25W
R2, R3, R5	- 10-kilo-ohm	- resistor, 0.25W
R6	- 1.2-kilo-ohm	- resistor, 0.25W
VR1	- 10-kilo-ohm	- preset
C1	- 10µF, 16V	- capacitor, electrolytic
C2, C5	- 0.01µF	- capacitor, ceramic disk
C3	- 4.7µF, 16V	- capacitor, electrolytic
C4	- 22µF, 16V	- capacitor, electrolytic
S1	- SP-10T	- rotary switch, single-pole, 10-way
Bat.	- 9V	- battery with connector

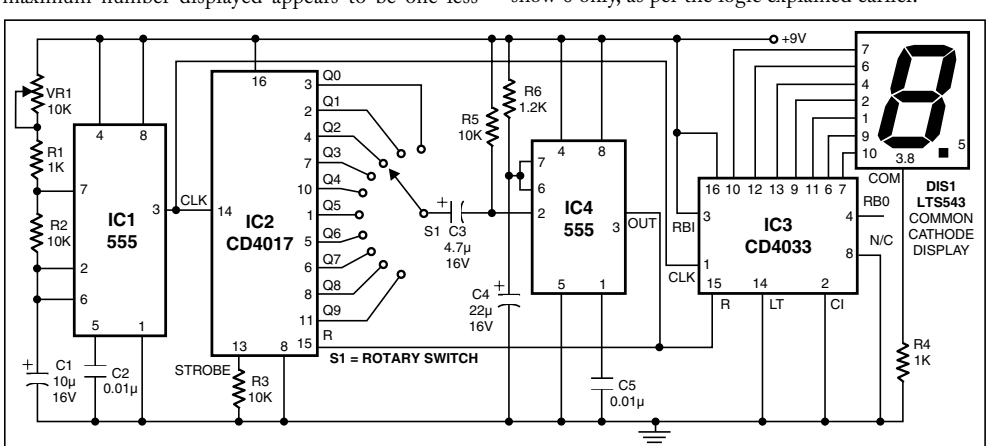


Fig. 3.12: Divide-by-N counter realisation using 555, CD4033 and CD4017

Project 21
Telephone call counter

This is a very useful add-on device that can be connected to telephone lines to count and display the number of incoming calls received in the absence of the subscriber. The circuit of a telephone call counter given in Fig. 3.13 comprises a decade counter IC CD4017B, a timer IC 555 and a few other discrete components.

The circuit may be divided into three sections: (a) ring detector, (b) call counter and (c) timer and relay controller. The ring detector circuit detects the incoming ring signals. The timer circuit is used to control a relay, which in turn controls the switching of ring signals to the ring detector section. The call counter is used to count the number of incoming calls (up to a maximum of nine calls) and activate the corresponding LED. The ring detector responds to the initial ringing signal pulse and ignores repetitive ringing pulses, which repeat until the called subscriber lifts the handset or the telephone exchange itself terminates them after time out.

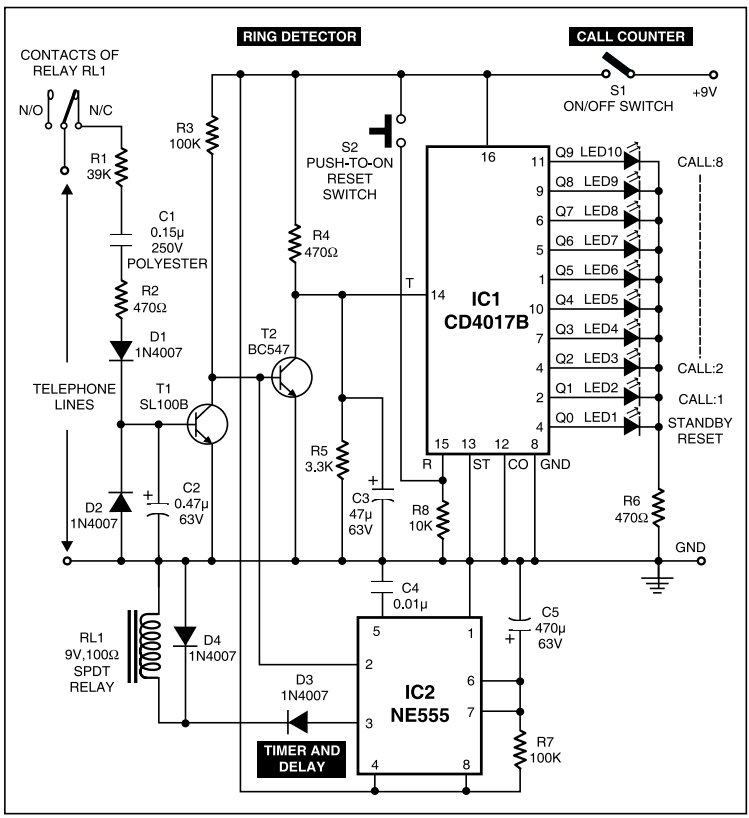


Fig. 3.13: Telephone call counter

When power switch S1 is turned on, the circuit gets +9V supply from the battery and the reset indicator LED1 lights up. If LEDl does not glow initially, press S2 to manually reset the counter CD4017B until LED1 glows. This is the standby condition in which the circuit waits for an incoming ring. In this standby mode, transistor T1 is in non-conducting state, while transistor T2 is forward biased via resistor R3 connected to positive supply rail, and hence its collector is at a low voltage level. As a result, pin 14 of IC1 is also at a low voltage level.

Now, when the telephone rings, AC voltage of about 75 volts RMS appears across the telephone lines, which are connected across input terminals of the circuit via N/C (normally closed) contacts of relay RL1 in a de-energised state. The series combination of resistors R1 and R2, capacitor C1 and diodes D1 and D2 limit the ringing signal amplitude at base of transistor T1. During positive half cycles of the ring signal, D1 starts

PARTS LIST		
IC1	- CD4017	- decade counter
IC2	- NE555	- timer
T1	- SL100B	- npn transistor
T2	- BC547	- npn transistor
D1-D4	- 1N4007	- rectifier diode
LED1-LED10	- LED	- 5mm red LED
R1	- 39-kilo-ohm	- resistor, 0.25W
R2, R4, R6	- 470-ohm	- resistor, 0.25W
R3, R7	- 100-kilo-ohm	- resistor, 0.25W
R5	- 3.3-kilo-ohm	- resistor, 0.25W
R8	- 10-kilo-ohm	- resistor, 0.25W
C1	- 0.15µF, 250V	- capacitor, polyester/ paper
C2	- 0.47µ, 63V	- capacitor, electrolytic
C3	- 47µ, 63V	- capacitor, electrolytic
C4	- 0.01µF	- capacitor, ceramic disk
C5	- 470µF, 63V	- capacitor, electrolytic
RL1	- relay 9V, 100Ω	- 1 C/O (changeover)
S1	- SPST	- toggle switch
S2	- push-to-on	- tactile switch
Batt.	- 9V	- battery

conducting and transistor T1 gets forward biased and it conducts. As a result, collector of T1 goes low to reverse bias transistor T2 and its collector goes high. The low-to-high transition at collector of T2 serves as a clock pulse at pin 14 of IC1, and the high state shifts from Q0 (pin 3) to Q1 (pin 2) and LED2 starts glowing, indicating call number 1.

Simultaneously, IC2 (which is wired as a monostable flip-flop) is triggered by high-to-low transition at collector of transistor T1, applied to trigger pin 2 of IC2. The timer IC2 outputs a short duration positive pulse, which energises relay RL1. As a result, the circuit is disconnected from the telephone lines for a predetermined period (decided by resistor R7 and capacitor C5 values) so that the call counter IC1 does not receive any clock until the ringing signal terminates. At the end of the mono time period, the circuit automatically returns to monitor the telephone line for the next call.

The above operation cycle is repeated for each succeeding call (ringing signal).

Note: This circuit is capable of indicating up to 9 calls received in the absence of the subscriber. It can be extended for a higher number of calls by cascading the required number of CD4017B ICs.

Project 22
Mains interruption counter with indicator

This circuit counts mains supply interruptions (up to 9) and shows the number on a 7-segment display. It may be used as add-on circuit for automobile battery chargers. Based on the number of mains interruptions, the user can extend the charging time for lead-acid batteries.

While Fig. 3.14 gives an overview of the connection of the mains interruption counter to the manual battery charger, Fig. 3.15 shows the circuit of the interruption counter with an indicator. A 9V (PP3 or 6F22) battery powers the add-on circuit.

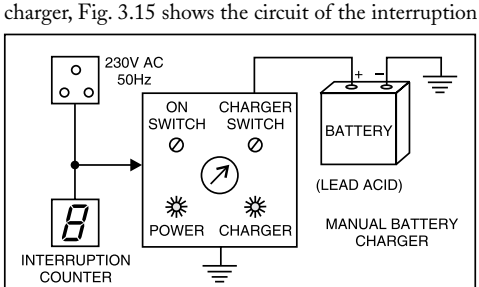


Fig. 3.14: Functional block diagram of the interruption counter showing connection to manual charger and battery

When 9V is applied to the circuit, IC2 is reset by the power-on-reset signal provided by capacitor C3 and resistor R5. Thus, the 7-segment display (DIS1)

PARTS LIST		
IC1	- MCT2E	- opto-coupler
IC2	- CD4033	- decade counter, 7-segment display driver
BR1	- Bridge	- rectifier, 1A
DIS1	- LT543	- 7-segment Common Cathode display
R1	- 33-kilo-ohm	- resistor 0.25W
R2	- 390-ohm	- resistor 0.25W
R3	- 120-ohm	- resistor 0.25W
R4	- 4.7K	- resistor 0.25W
R5	- 2.2-kilo-ohm	- resistor 0.25W
R6	- 270-ohm	- resistor 0.25W
C1	- 0.22µF, 250V	- capacitor polyester
C2	- 100µF, 63V	- capacitor electrolytic
C3	- 1µF, 25V	- capacitor electrolytic
C4	- 10µF, 25V	- capacitor electrolytic
S1	- SPST	- switch push-to-on
Batt.	- PP9	- battery, 9V

shows 0. The 230V AC mains is fed to mains-voltage detection optocoupler IC MCT2E (IC1) via capacitor C1, resistors R1 and R2, followed by bridge rectifier BR1, followed by smoothing capacitor C2 and current-limiting resistor R2. Illumination of the LED inside optocoupler IC1 activates its internal photo transistor, and clock input pin 1 of IC2 is pulled to low level. This signal is used as a clock for IC CD4033.

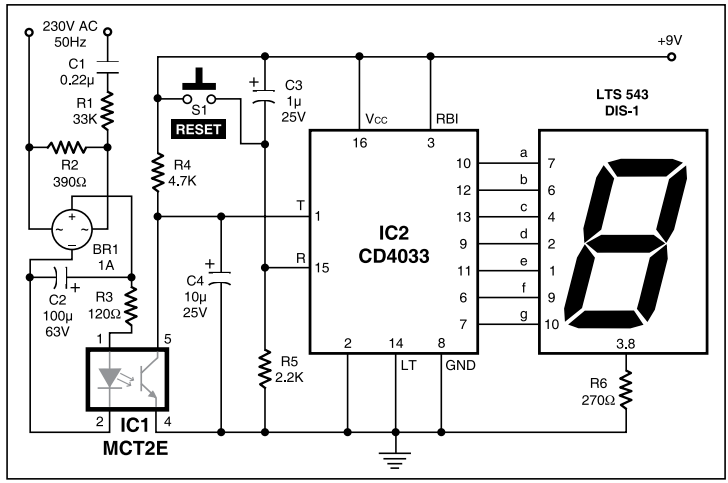


Fig. 3.15: Circuit of the interruption counter with indicator

The clock pulses are applied to clock input pin 1 of counter, while its clock-enable pin 2 is held low to enable the counter. Seven-segment, common-cathode display DIS1 (LTS543) indicates the mains interruption count. Capacitor C2 provides a small turn-on delay for the display.

When mains fails for the first time, clock input pin 1 of IC2 again goes high and display DIS1 shows 1. When mains resumes, pin 1 of IC2 goes low and DIS1 continues to show 1. When mains fails for the second time, clock input pin 1 of IC2 goes high and display DIS1 shows 2. When mains resumes, pin 1 of IC2 again goes low and DIS1 continues to show 2. This way, the counter keeps incrementing by 1 on every successive mains interruption. After noting the interruption during a predetermined charging period, the counter may be reset to 0 using a reset switch.

Project 23
Timer for students

Nowadays, students are required to answer a set of objective type of questions in a given time, which may typically be 15 minutes, 30 minutes, or one hour. Speed and accuracy win the race. Practice helps in achieving it. The timer employs a 14-stage binary ripple counter cum oscillator IC CD4060B. The pin configuration with signals at its various pins is shown in Fig. 3.16, while its internal simplified logic diagram is shown in Fig. 3.17

An RC (resistor-capacitor) or crystal based oscillator can be readily configured using in-built logic gates of CD4060 IC brought out on its pins 9, 10 and 11, as shown in Figs. 3.18 and 3.19 respectively.

Similarly, a low frequency (normally below 1 MHz) crystal oscillator can be configured. Typical component values for 32 kHz and 500 kHz oscillator are shown in Table 3-6.

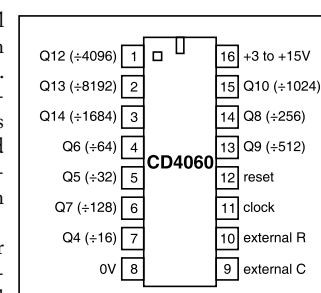


Fig. 3.16: Pin configuration/function diagram of CD4060

The timer circuit configured around CD4060 IC gives an alarm

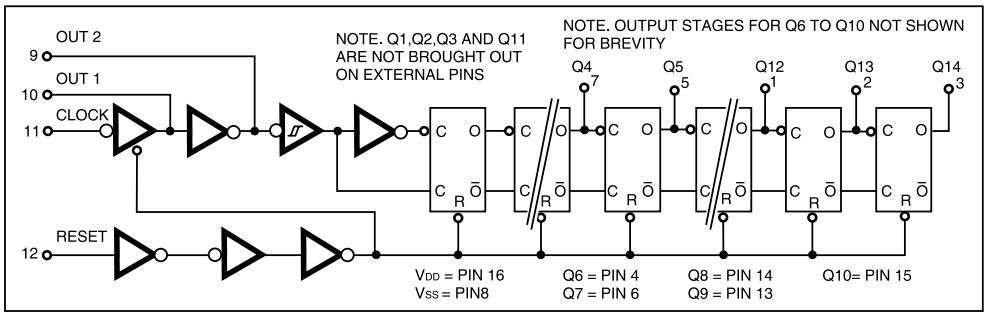
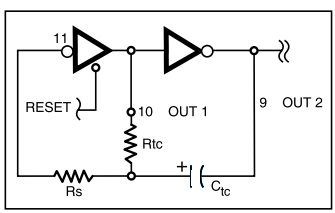


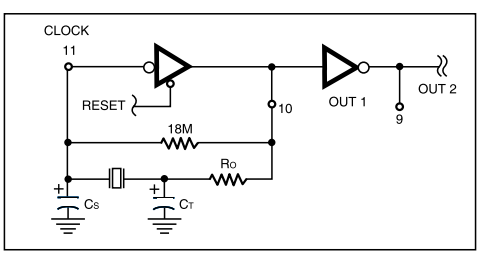
Fig. 3.17: Internal simplified logic diagram of CD4060



$$f = \frac{1}{2.3R_{TC}C_{TC}}$$

If 1kHz ≤ f ≤ 100 kHz and $2R_{TC} < R_S < 10R_{TC}$ (if in Hz, R in ohms, C in farads) The formula may vary for other frequencies. Recommended maximum value for the resistors is 1 MΩ.

Figs. 3.18: Oscillator circuit using RC configuration (formulae for frequency given along-side)



Figs. 3.19: Configuring a crystal oscillator

TABLE 3-6

Component values for crystal oscillator

Chracteristic	500kHz Circuit	32kHz Circuit	Unit
Crystal Characteristics Resonant Frequency	500	32	Khz
External Resistor/ Capacitor values			
R_O	47	750	kΩ
C_T	82	82	pF
C_S	20	20	pF

after a preset time of 30 minutes. As also a few beeps at half the selected time period is shown in Fig. 3.20. The timer can be programmed for other periods as well. The alarm can be reset for a fresh start.

Here, the oscillator frequency may be set using potmeter VR1 (multiturn potmeter), in series with resistor R1 and capacitor C1. Potmeter VR1 is adjusted for a time period of 15 minutes at output Q12 (pin 2). The output Q13 (pin 3) will go high after 30 minutes.

PARTS LIST

IC1	- CD4060	- 14-stage divider with built-in oscillator
IC2	- NE555	- timer
T1	- BC547	- npn transistor
T2	- SL100	- npn transistor
D1-D3	- 1N4148	- switching diode
R1	- 47-kilo-ohm	- resistor, 0.25W
R2	- 1-mega-ohm	- resistor, 0.25W
R3, R6, R9	- 10-kilo-ohm	- resistor, 0.25W
R4	- 470-ohm	- resistor, 0.25W
R5	- 39-kilo-ohm	- resistor, 0.25W
R7	- 4.7-kilo-ohm	- resistor, 0.25W
R10	- 3.3-kilo-ohm	- resistor, 0.25W
R11	- 5.6-kilo-ohm	- resistor, 0.25W
VR1	- 1-mega-ohm	- resistor 0.25W
C1	- 0.1µF	- capacitor, ceramic disk
C2	- 47µF, 16V	- capacitor, electrolytic
C3	- 0.01µF	- capacitor, ceramic disk
C4, C5	- 0.1µF	- capacitor, ceramic disk
C6	- 100µF, 16V	- capacitor, electrolytic
PZ1	- buzzer	- piezo buzzer
LS1	- 8-ohm, 1W	- loudspeaker (miniature LS can be used)
S1	- SPST	- push-to-on tactile switch
Batt.	- 1.5V x 4	- battery

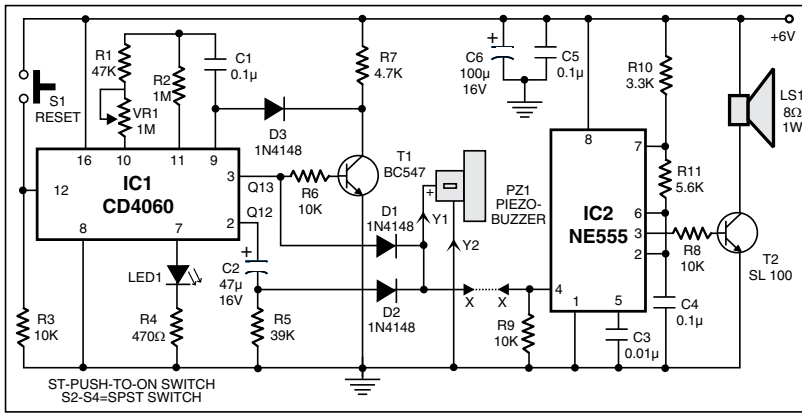


Fig. 3.20: Schematic circuit diagram of timer for students

reset button momentarily resets all the outputs of CD4060 to zero and the timer starts again.

Piezo-electric buzzers are reliable and rugged, and serve as cheap audio alarms. They are available for operation in continuous and intermittent modes. However, if you require louder sound, then you have an optional 555 timer based circuit. The 555 IC is wired up as an astable multivibrator. This can be brought into the circuit by shorting points x-x in the circuit. Under the circumstance, the piezo buzzer needs to be disconnected from the circuit at the points marked Y1, Y2 and Y3.

When Q13 output goes high, the 3-terminal piezo-buzzer becomes active and gives out a tone. This buzzer also beeps for a few seconds at half the set time. Transistor T1 prevents further oscillations after the elapsed time. Red LED1 is used as an activity indicator. The circuit is powered by a 6V battery. Pressing the

Project 24
DICE with 7-segment display

A digital dice circuit can be easily realised by using an astable oscillator circuit followed by a counter, display driver and a display, as shown in Fig. 3.21.

Here we have used a timer NE555 as an astable oscillator with a frequency of about 100 Hz. Decade counter IC CD4026 or CD4033 (whichever available) can be used as a counter-cum-display driver. When using CD4026, pin 14 (cascading output) is to be left unused (open); however in case of CD4033, pin 14 serves as lamp test pin and the same is to be grounded.

The complete schematic of the digital dice is shown in Fig. 3.21. The circuit uses only a handful of components. Its power consumption is also quite low because of use of CMOS ICs, and hence it is well suited for battery operation. In this circuit, two tactile switches S1 and S2 have been provided. While switch S2 is used for initial resetting of the display to '0'; pressing switch S1 simulates throwing of the dice by a player.

When the battery is connected to the circuit, the counter and display section around IC2 (CD4026/4033) is energised and the display would normally show '0', as no clock input is available. Should the display show any other decimal digit, you may press reset switch S2 so that display shows '0'. To simulate throwing of dice, the player has to press start switch S1, briefly. This extends the supply to the astable oscillator configured around IC1 as well as capaci-

TABLE. 3-7

Decoded segment outputs for counts 0 through 9.

Truth Table of 4026 and display driver IC

Count	a	b	c	d	e	f	g	h
0	●	●	●	●	●	●		●
1		●	●					●
2	●	●		●	●		●	●
3	●	●	●	●			●	●
4		●	●			●	●	●
5	●		●	●		●	●	
6	●		●	●	●	●	●	
7	●	●	●				●	
8	●	●	●	●	●	●	●	
9	●	●	●	●		●	●	

● = segment on. h is used to drive other counters.

7-segment display

tor C1 (through resistor R1), which charges to the battery voltage. Thus, even after switch S1 is released, the astable circuit around IC1 keeps producing the clock until capacitor C1 discharges sufficiently.

Thus, for the duration of depression of switch S1 and discharge of capacitor C1 thereafter, clock pulses are produced by IC1 and applied to clock pin 1 of counter IC2. The count of IC2 advances at a fairly high frequency (5 kHz) for the eyes to perceive on the fast changing display, until C1 discharges sufficiently to deactivate IC1.

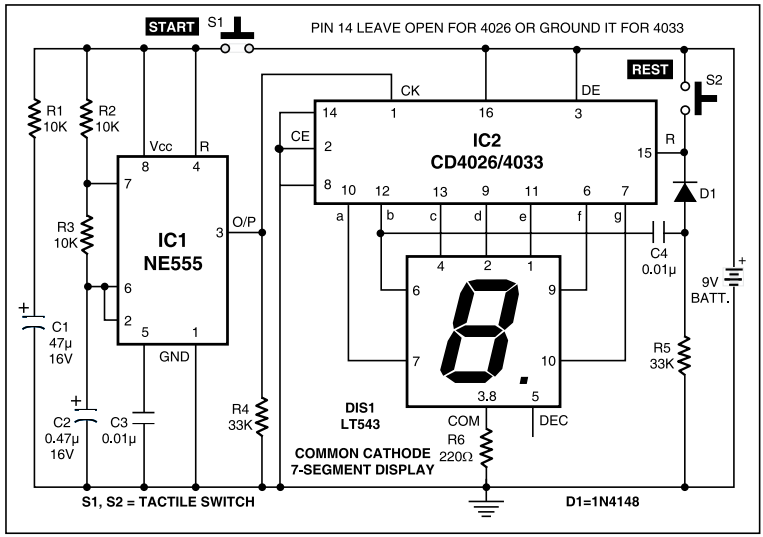


Fig. 3.21: Digital dice circuit

When the oscillations from IC1 stop, the last (random) count in the counter IC2 can be viewed on the 7-segment display. This count would normally lie between 0 and 6, since at the leading edge of every seventh clock pulse, the counter is reset to zero. This is achieved as follows.

Observe the behaviour of 'b' segment output in Table 3-7. On reset, at count 0 until count 4, the segment 'b' output is high. At count 5, it changes to low level and remains so during count 6. However, at start of count 7, the output goes from low-to-high state. A differentiated sharp high pulse through C-R combination of C4-R5 is applied to reset pin 15 of IC2, to reset the output to '0' for a fraction of a pulse period (which is not visible on the 7-segment display). Thus, if the clock stops at seventh count, the display will read zero.

There is a probability of one chance in seven that display would show '0.' In such a situation, the concerned player is given another chance until the display is non-zero.

Note: Although it is quite feasible to inhibit display of '0' and advance the counter by 1, it makes the circuit somewhat complex and such a modification has therefore not been attempted.

PARTS LIST

IC1	- NE555	- timer
IC2	- CD4026/4033	- decade counter, 7-segment display driver
D1	- 1N4148	- switching diode
DIS1	- LT543	- 7-segment common cathode LED display
R1-R3	- 10-kilo-ohm	- resistor, 0.25W
R4,R5	- 33-kilo-ohm	- resistor, 0.25W
R6	- 220-ohm	- resistor, 0.25W
C1	- 47µF, 16V	- capacitor, electrolytic
C2	- 0.47µF, 16V	- capacitor, electrolytic
C3-C4	- 0.01µF	- capacitor, ceramic disk
S1, S2	- SPST	- push-to-on tactile switch
Batt.	- PP9	- 9V battery

SECTION 4
Interesting miscellaneous projects

This section covers miscellaneous projects of general interest. For better performance, some of these projects need to be assembled on a printed circuit board (e.g., project assemblers 30-32, 34, 37, 38 and 41), while other projects may be assembled using a Breadboard or stripboard.

Project 25
Simple smoke alarm

This is a sensitive and inexpensive smoke detector-cum-alarm. It warns occupants in a building of impending fire. It uses an infrared photo-interrupter module as the sensor, a Darlington pair-based amplifier to activate a piezo-buzzer and an LED as warning device.

The photo-interrupter module (Fig. 4.1) consists of a gallium-arsenide infrared LED and a silicon phototransistor in a plastic housing. The slot (recess) between the infrared diode and the phototransistor allows a part of the beam from IR LED to impinge upon the phototransistor detector, allowing it to conduct when powered. Any interruption of the IR beam due to smoke or any other obstruction causes the phototransistor to stop conduction.

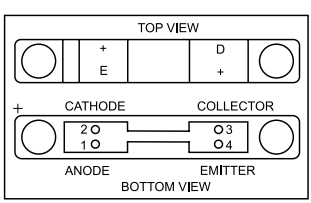


Fig. 4.1: H21A1 photo-interrupter (top and bottom views)

When the smoke enters the gap between the IR LED and phototransistor of the interrupter module (IC1), the IR rays falling on the phototransistor are obstructed, the phototransistor is cut-off, and its collector is pulled towards positive battery rail. This causes forward biasing of the Darlington pair of npn transistors T1 and T2, which are normally in cut-off state during conduction of the phototransistor because its collector is then at a low potential (about +0.65V). Conduction of Darlington pair when smoke penetrates the gap in the photo-interrupter module activates the buzzer as well as LED1, which lights up.

When the smoke in the gap clears up, the light from the IR LED again falls on the phototransistor and it starts conducting. As a result, Darlington-pair transistors stop conducting and the buzzer as well as LED1 turn off.

For optimum sensitivity, adjust presets VR1 to control the sensitivity of the photo-interrupter module, while VR2 may be adjusted to control the biasing of the Darlington-pair and, hence, its sensitivity.

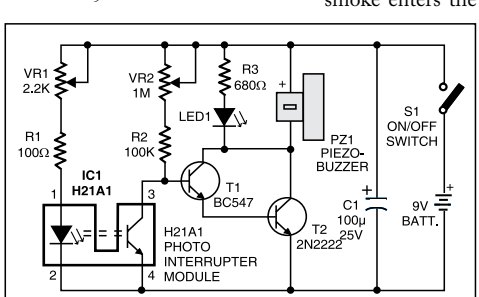


Fig. 4.2: Schematic diagram of a simple smoke alarm

PARTS LIST		
IC1	- H21A1	- photo-interrupter module
T1	- BC547	- npn transistor
T2	- 2N2222	- npn transistor
LED1	- 5mm LED	- red LED
R1	- 100-ohm	- resistor, 0.25W
R2	- 100-kilo-ohm	- resistor, 0.25W
R3	- 680-ohm	- resistor, 0.25W
VR1	- 2.2-kilo-ohm	- preset resistor
VR2	- 1-meg-ohm	- preset resistor
C1	- 100µF, 25V	- electrolytic capacitor
S1	- SPST	- toggle switch
PZ1	- piezo buzzer	
Batt.	- PP9	- 9V battery

Project 26
Concealed AC mains line detector

This simple and low-cost circuit, given in Fig. 4.3, can be used for detecting the presence of AC mains line without directly touching the line. It can even detect discontinuity/broken points in concealed AC mains wiring. Whenever the test probe is taken close to any live line, the buzzer sounds and LED1 glows, indicating the presence of AC. It can detect presence of AC mains from a distance of about 30 cm from the mains AC line.

The circuit uses an n-channel junction FET transistor BFW11 (T1) for detecting the presence of mains 50Hz AC supply. In the absence of the AC mains signal (with the gate of FET open), the drain voltage of JFET is very low (below 100 mV). However, when the probe, connected to the gate of JFET is brought closer to 50Hz AC mains line, it cuts off during negative half cycles. This causes transistor T2 to conduct, and its collector voltage drops to almost the ground potential. As a result, capacitor C1, which is charged to battery voltage of 3 volts via resistor R3, discharges and causes pnp transistor T3 to conduct and sound the buzzer. The LED1 also lights to indicate the presence of AC source in the vicinity.

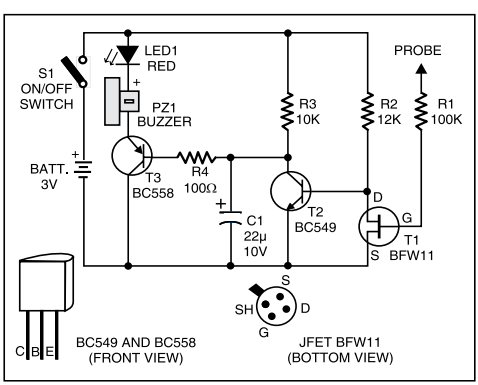


Fig. 4.3: Concealed AC mains line detector circuit

PARTS LIST		
T1	- BFW11	- JFET N-channel
T2	- BC549	- npn transistor
T3	- BC558	- pnp transistor
LED1	- 5mm	- red LED
PZ1	- Piezo buzzer	
R1	- 100-kilo-ohm	- resistor, 0.25W
R2	- 12-kilo-ohm	- resistor, 0.25W
R3	- 10-kilo-ohm	- resistor, 0.25W
R4	- 100-ohm	- resistor, 0.25W
C1	- 22µF, 10V	- electrolytic capacitor
Batt.	- 1.5x2 AAA	- 3V battery
S1	- SPST	- switch toggle
	- Probe	- telescopic antenna

During the positive half cycles of the AC, capacitor C1 doesn't charge back substantially via resistor R3 and as such transistor T3 remains 'on' to give continuous audio-visual indication, as long as the probe is kept near the AC source. The circuit may provide similar indication even in the case of DC supply with sufficient AC ripple.

The circuit operates off 3V DC via two small pentorch cells (AAA type). You may use a 10cm steel rod or telescopic antenna for the probe.

Project 27
Speed control of DC motor using pulse-width modulation

Pulse-width modulation (PWM), or duty-cycle variation methods, are commonly used in speed control of DC motors. The duty cycle is defined as the percentage of digital high to digital low plus digital high pulse-width during a PWM period.

Fig. 4.4 shows the 5V pulses with 0% through

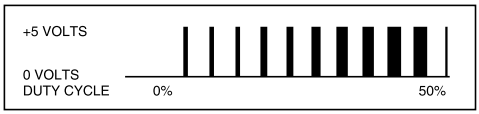


Fig. 4.4: 5V pulses with 0% through 50% duty cycle

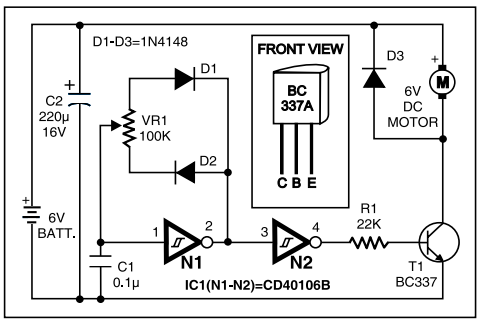


Fig.4.5: Circuit of DC motor speed control using PWM method

50% duty cycle. The average DC voltage value for 0% duty cycle is zero; with 25% duty cycle the average value is 1.25V (25% of 5V). With 50% duty cycle, the average value is 2.5V, and if the duty cycle is 75%, the average voltage is 3.75V, and so on. The maximum duty cycle can be 100%, which is equivalent to a DC waveform. Thus, by varying the pulse-width, we can vary the average voltage across a DC motor and, hence, its speed.

The circuit of a simple speed controller for a mini DC motor, such as that used in tape recorders and toys, is shown in Fig. 4.5. Here, N1 is an inverting Schmitt trigger configured as an astable multivibrator with constant period but variable duty cycle.

Although the total in-circuit resistance of VR1 during a complete cycle is 100 kilo-ohms, the part used during positive and negative periods of each cycle can be varied by changing the position of its wiper contact to obtain variable pulse-width. Schmitt gate N2 simply acts as a buffer/driver to drive transistor T1 during positive incursions at its base. Thus, the average amplitude of DC drive pulses or the speed of motor M is proportional to the setting of the wiper position of VR1 potmeter. Capacitor C2 serves as a storage capacitor to provide stable voltage to the circuit. Thus, by varying VR1 the duty cycle can be changed from 0% to 100% and the speed of the motor from stopped condition to full speed in an even and continuous way. The diodes effectively provide different timing resistor values during charging and discharging of timing capacitor C1.

PARTS LIST		
IC1	- CD40106	- quad 2-input Schmitt gate
T1	- BC337	- npn transistor
D1-D3	- 1N4148	- switching diode
R1	- 22-kilo-ohm	- resistor 0.25W
VR1	- 100-kilo-ohm	- potmeter
C1	- 0.1 µF	- capacitor ceramic disk
C2	- 220µF, 16V	- capacitor electrolytic
Batt.	- 1.5Vx4 AAA	- 6V battery

The pulse or rest period is approximately given by the following equation:

Pulse or Rest period ≈ 0.4×C1 (Farad)×VR1 (ohm) seconds.

Here, use the in-circuit value of VR1 during pulse or rest period, as applicable. The frequency will remain constant and is given by the equation:

Frequency ≈ 2.466/(VR1.C1) ≈ 250Hz (for VR1=100 kilo-ohms and C1=0.1µF)

The recommended value of in-circuit resistance should be greater than 50 kilo-ohms but less than 2 mega-ohms, while the capacitor value should be greater than 100 pF but less than 1 µF.

Project 28
IR to RF converter

Controlling devices/functions by sending and receiving coded IR signals is quite common. This method is used for controlling TVs, VCRs, DVDs, air-conditioners, vending machines and a host of other equipment. The most common code formats used are the RC5 developed by Philips and pulse coding format developed by NEC. However, these remotes work over a short distance of 5 metres or so. But, if we convert these coded signals into modulated RF signals and demodulate them at the receiver end, the control range

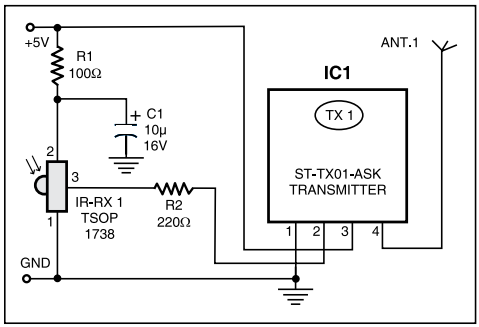


Fig. 4.6: IR to RF converter/transmitter

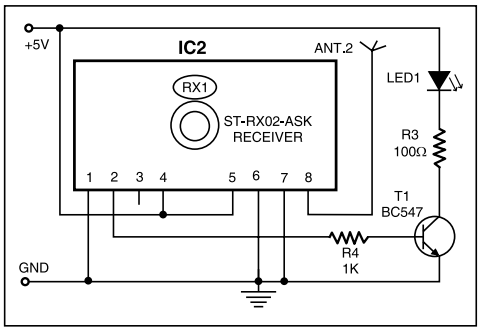


Fig. 4.7: RF receiver to IR converter

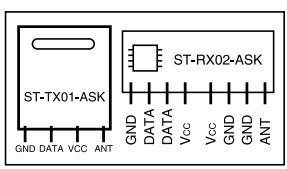


Fig. 4.8: Pin configuration of typical RF transmitter and receiver modules (back view)

can be increased to about 200 metres.

Here is a simple circuit using which you can convert IR signals into RF signals, transmit these to a remote location, and decode them using a compatible RF receiver. The coded IR signals from the IR remote are detected by the typical IR receiver module TSOP1738, as shown in Fig. 4.6. The detected IR code output is used for modulating at 433.92 MHz RF transmitter via its pin 2, as shown in Fig. 4.6.

The RF transmitter is an AM/ASK transmitter with typical power output of 16 dBm at 5V with 60mA current consumption during transmission. A quarter-wave (17.3cm) antenna is adequate for the purpose. A 433.92MHz compatible receiver, as shown in Fig. 4.7, can be employed for receiving and detecting the transmitted code for further use. Here, the detected output is used to light up LED1, to indicate when the coded pulse train is being received.

Low-cost hybrid transmitters employing SAW devices and compatible receivers are now commonly available. Pin configuration (back view) of typical RF transmitter and receiver modules is shown in Fig. 4.8.

PARTS LIST

IC1	- ST-TX01-ASK	- 433 MHz RF transmitter module
IC2	- ST-RX02-ASK	- 433 MHz RF receiver module
IR-RX1	- TSOP1738	- 38 KHz IR Receiver module
T1	- BC547	- npn transistor
LED1	- 5mm	- red LED
R1, R3	- 100-ohm	- resistor, 0.25W
R2	- 220-ohm	- resistor, 0.25W
R4	- 1-kilo-ohm	- resistor, 0.25W
C1	- 10µF, 16V	- electrolytic capacitor
	- Power supply	- 4X1.5V cells
	- antennas	- flexible insulated wire, 35 cm

Project 29
Contactless telephone ringer

This contactless telephone ringer can provide an indication of the incoming telephone ring at a remote point, such as a kitchen or bedroom, provided the telephone lines of the premises are passing via these remote locations, while the actual telephone instrument is far away, say in the drawing room.

Contactless remote ringer is shown in Fig. 4.9. Circuit is implemented by winding five or more turns of a short hookup insulated wire around one of the twin telephone wires. Note that when your telephone

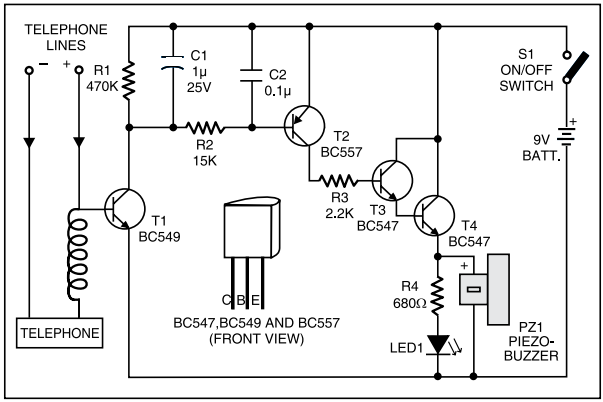


Fig. 4.9: Contactless remote ringer

PARTS LIST		
T1	- BC549	- npn transistor
T2	- BC557	- pnp transistor
T3, T4	- BC547	- npn transistor
LED1	- 5mm	- red LED
PZ1	- Piezo buzzer	
R1	- 470-kilo-ohm	- resistor, 0.25W
R2	- 15-kilo-ohm	- resistor, 0.25W
R3	- 2.2-kilo-ohm	- resistor, 0.25W
R4	- 680-ohm	- resistor, 0.25W
C1	- 1µF, 25V	- electrolyte capacitor
C2	- 0.1µF	- ceramic disk capacitor
Batt.	- PP9	- 9V battery
S1	- SPST	- toggle switch
	- 20 SWG, 10cm	- insulated hookup wire

rings, AC signal of the ring frequency is generated in the telephone line, which causes a fluctuating electric field around the telephone cable and develops a small induced voltage on the hookup cable. This induced voltage, when connected to the base of transistor T1, forward biases it and it conducts when ring is passing through the telephone cable. Consequently, transistors T2 through T4 also conduct. As a result, the piezo buzzer sounds and LED1 glows, which indicates that the telephone is ringing.

In case the telephone lines are not passing the remote location, then you may simply extend the two leads (from emitter of transistor T4 and ground) and connect the buzzer and LED1 away from the rest of the circuit at a remote location.

Project 30
Preamplifier (signal booster) for FM band

Even though there are a large number of FM transmitters in our country, the range of satisfactory reception is limited to around 40 km due to the inherent disadvantages of VHF line-of-sight transmission. Reception at fringe areas is poor and noisy. At the receiving site, one possible solution to overcome this problem is to use a good quality pre amplifier with a dipole as the antenna. The following circuit is designed for such areas where the transmission is weak and noisy. This pre amplifier amplifies weak signals embedded in noise to a sufficient level, and as a result the standard sensitivity of an FM radio (about 5µV) is increased up to 1µV.

Preamplifier (signal booster) for FM band is shown in Fig. 4.10. The heart of the circuit is a high frequency npn transistor (C2570 or C1730) configured to operate in the common-base mode with a low collector current. This ensures a good signal-to-noise ratio. Inductors L1 and L2, along with capacitors C1 and C2, ensure proper reception over the entire FM band (88-108 MHz). The signal to be amplified is coupled to the emitter of transistor T1 via capacitor C1. The tuned circuit at the collector of T1 is tuned by coil L2 and trimmer

PARTS LIST		
T1	- C1730/C2570/BF495	- npn RF transistor
R1	- 1-kilo-ohm	- resistor, 0.25W
R2	- 1-meg-ohm	- resistor, 0.25W
R3	- 100-ohm	- resistor, 0.25W
C1, C6	- 1nF	- ceramic disk capacitor
C2	- 27pF	- ceramic disk capacitor
C3	- 22nF	- ceramic disk capacitor
C4, C8	- 100nF	- ceramic disk capacitor
C5	- 100µF, 12V	- electrolytic capacitor
VC1	- 22pF	- trimmer capacitor
Batt.	- 4x1.5V	- 6V battery
Ant	- 1/4λ	- telescopic for input

capacitor VC1 for the maximum response at mid frequency (around 98 MHz), so that the entire FM band is covered.

You may substitute T1 with any other HF transistor having a cut-off frequency (Ft) of 250 MHz or so, and current amplification factor in common emitter configuration (hfe) of minimum 30 (e.g., BF495). The use of these transistors could provide a gain of approximately 28 dB at 112 MHz with a noise figure of 1.3 dB.

The power supply for the circuit can be between 3.6V and 9V. The circuit draws only approximately 1.5mA when powered by a 6V battery. For inductor L1, use 20SWG enameled copper wire and close wind five turns on any smooth rod of 5mm diameter and slip the coil out of the rod and use it in the circuit (as air core coil). Similarly, for L2, use 24SWG enamelled copper wire and space wind six turns on a rod of 5 mm diameter. Slip the coil out of the rod. The length of the coil should be approximately 8 mm.

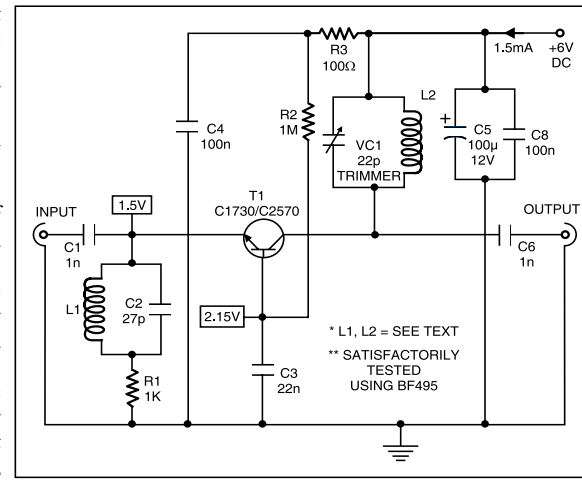


Fig. 4.10: Circuit of preamplifier (signal booster) for FM band

All component leads should be cut as short as possible when the circuit is assembled on a PCB.

Connect the output of this preamplifier at the antenna terminal of the FM receiver. Tune the receiver to a weak station. Apply 6V DC power to the circuit. Tune the trimmer capacitor VC1 for resonance (marked by an improvement in reception) using a plastic/teflon alignment tool.

Project 31
Condenser mike amplifier

One often needs a sensitive sound pick-up device, whether to be used as a simple microphone or a more exotic device, such as a sound operated alarm, a bugging device or a sound operated flash (for stop action photography)—the list is unending.

This circuit employs a condenser microphone as the transducer. Since output of the condenser microphone is quite low,

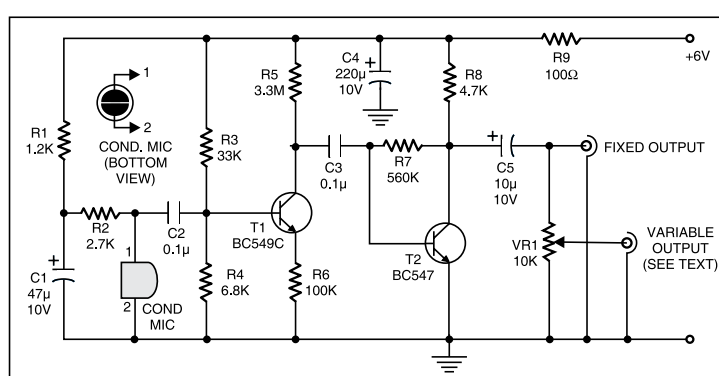


Fig. 4.11: Condenser mike amplifier circuit

it usually has an FET amplifier built into its case. This inbuilt amplifier is powered by the R1-R2 resistor network.

The output of the condenser microphone is fed to a two-stage amplifier. Transistor T1 (BC549C), utilising current series feedback, forms the first stage. The second stage, comprising transistor T2 (BC547B), is connected in the voltage shunt feedback configuration. These two stages provide sufficient gain to pick up even the slightest whisper.

Output of the microphone amplifier can be made variable by connecting a 10k potentiometer or preset as shown in Fig. 4.11.

PARTS LIST		
T1	- BC549	- npn transistor
T2	- BC547	- npn transistor
R1	- 1.2-kilo-ohm	- resistor, 0.25W
R2	- 2.7-kilo-ohm	- resistor, 0.25W
R3	- 33-kilo-ohm	- resistor, 0.25W
R4	- 6.8-kilo-ohm	- resistor, 0.25W
R5	- 3.3-mega-ohm	- resistor, 0.25W
R6	- 100-kilo-ohm	- resistor, 0.25W
R7	- 560-kilo-ohm	- resistor, 0.25W
R8	- 4.7-kilo-ohm	- resistor, 0.25W
R9	- 100-ohm	- resistor, 0.25W
VR1	- 10-kilo-ohm	- potmeter
C1	- 47µF, 10V	- electrolytic capacitor
C2, C3	- 0.1µF	- ceramic disk capacitor
C4	- 220µF, 10V	- electrolytic capacitor
C5	- 10µF, 10V	- electrolytic capacitor
MIC1	- condenser mic	

Project 32
Cordless FM mike

FM transmission scores over AM transmission, as AM transmission lacks the fidelity of reception while FM reception is rather clear, which is important, especially for instrumental music. The transmission is received by an ordinary FM radio.

Cordless FM mike circuit is shown in Fig. 4.12. The first transistor T1 is wired as a preamplifier for the microphone. Its output is coupled through capaci-

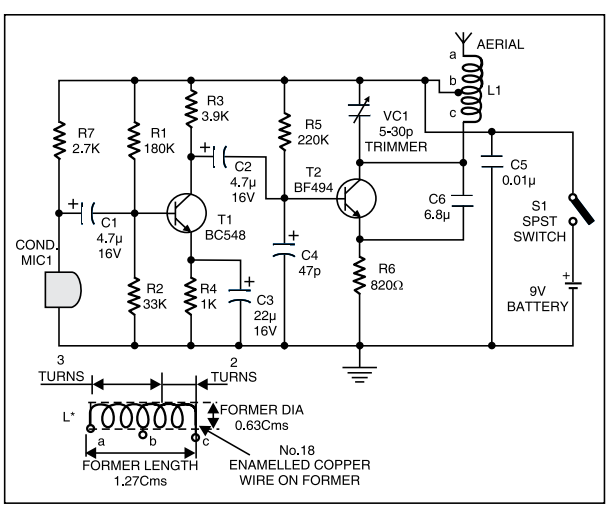


Fig. 4.12: Cordless FM mike circuit

PARTS LIST		
T1	- BC548	- npn transistor
T2	- BF494	- npn transistor
R1	- 100-kilo-ohm	- resistor 0.25W
R2	- 33-kilo-ohm	- resistor 0.25W
R3	- 3.9-kilo-ohm	- resistor 0.25W
R4	- 1-kilo-ohm	- resistor 0.25W
R5	- 220-kilo-ohm	- resistor 0.25W
R6	- 820-ohm	- resistor 0.25W
R7	- 1-kilo-ohm	- resistor 0.25W
C1, C2	- 4.7µF, 16V	- capacitor electrolytic
C3	- 22µF, 16V	- capacitor electrolytic
C4	- 47pF	- capacitor ceramic disk
C5	- 0.01µF	- capacitor ceramic disk
C6	- 6.8pF	- capacitor ceramic disk
VC1	- 5-30pF	- trimmer capacitor
L1	- refer Fig.	- inductor
MIC1	- Condenser Mike	
	- Antenna	- 13 cm flexible insulated wire

tor C2 to the mixer-cum-oscillator stage wired around BF494 transistor T2. Coil L and trimmer VC1 form the tank circuit for producing the carrier frequency. Trimmer capacitor VC1 can be adjusted to obtain the desired carrier frequency. The coil L1 must be wound exactly as shown in the separate figure. Use an insulator for the core and for winding use 18SWG enamelled copper wire. This FM mike is expected to provide good reception up to a distance of 10-15 metres from the mike.

The assembled unit should be fixed inside a metal case, so that hand capacitance and other stray capacitances do not change the carrier frequency. About 13cm long wire should be attached to the free end of the coil to act as an aerial. The wire must be extended out of the case and insulated, so that it does not touch the metal case at any place. The supply can be provided by a small PP9, 9V battery for compactness.

After switching the unit on, the FM radio can be tuned to FM mike's carrier frequency such that when music is played into the mike, it can be heard through the radio.

Project 33
Laser controlled on/off switch

By focusing a laser beam on LDR1 the connected load or gadget can be activated through the relay, whereas by focusing a laser beam on LDR2 we can switch off the gadget. The 555 timer is configured to operate in bistable mode.

The light resistance of a typical LDR (also known as photocell) is less than 100 kilo-ohm, while its dark resistance is greater than 10 meg-ohm.

Here the timer is used in its non-oscillatory bistable mode by leaving the discharge pin 7 in open state and making use of the two comparators (upper and lower). Due to internal biasing resistors, the '+' terminal (non-inverting) of lower comparator is held at 1/3rd Vcc, while terminal (inverting) of upper comparator is held at 2/3rd Vcc. Thus, during dark condition of both LDRs, trigger pin 2 ('–' terminal) of the lower comparator is greater than 1/3Vcc and hence its output is low. Similarly, output of upper comparator is also low, because its + terminal (threshold pin 6) is pulled towards ground via resistor R2 (1-meg-ohm). In this state, the

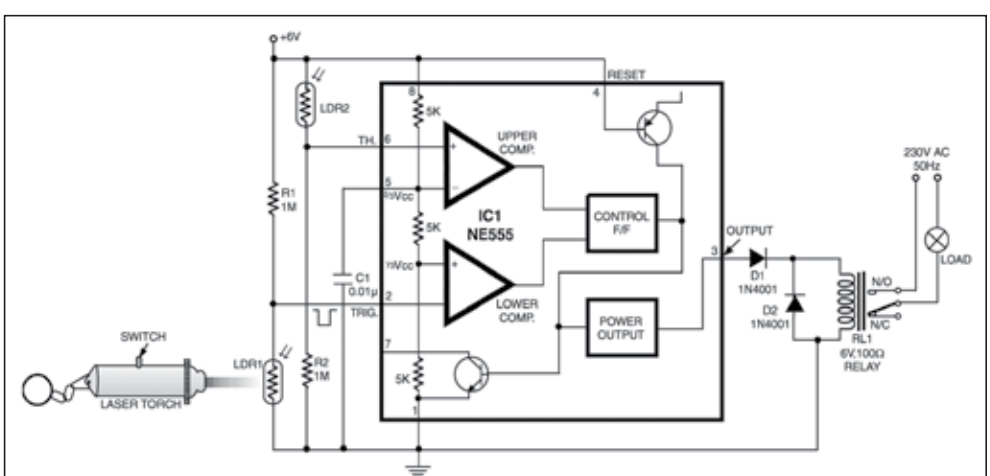


Fig. 4.13: Laser controlled on/off switch

output pin 3 is at near ground potential.

When laser light is focused on LDR1, its resistance falls and trigger pin 2 goes below 1/3Vcc, and the lower comparator output goes high to set the control flip-flop inside 555 timer. This toggles the output to high state to energise the relay RL1, and the supply to load is switched on through contacts of the relay. The condition of 555 output remains so even when laser light is turned off. To switch off the load, laser light is focused on LDR2, which causes threshold pin 6 to rise above 2/3Vcc. This causes output of upper comparator to go high and reset the internal control flip-flop, and thus output at pin 3 of timer 555 goes low to de-energise relay RL1 and switch off the load (refer Fig. 4-13).

A laser pointer is now easily available in the market, which can be used to operate this device. Its range is around 500 metres. Aiming (aligning) the laser beam exactly on to the LDR is a practical problem.

This circuit is very useful in switching on/off a fan at night without getting off the bed. It can also be used for controlling a variety of other devices, like a radio or music system. The limitation is that the circuit is operational only in dark or dull-lit environments.

PARTS LIST

IC1	- NE555	- timer
D1, D2	- 1N4001	- rectifier diode
LDR1, LDR2	- light resistance <100k dark resistance >10m	
R1, R2	- 1-mega-ohm	- resistor, 0.25W
C1	- 0.01µF	- ceramic disk capacitor
RL1	- 6V, 1 C/O	- relay contact rating >1A
	- laser pointer	
	- power supply	- 6V DC

Project 34
Phone broadcaster

Here is a simple yet very useful circuit, which can be used to eavesdrop on a telephone conversation. The circuit can also be used as a wireless telephone amplifier.

One important feature of this circuit is that it derives its power directly from the active telephone lines, and thus avoids use of any external battery or other power supplies. This not only saves a lot of space but also money. It consumes very low current from telephone lines without disturbing its performance. The circuit is very tiny and can be built using a single-IC type veroboard that can be easily fitted inside a telephone connection box of 3.75 cm × 5 cm.

The circuit consists of two sections, namely, automatic switching section and FM transmitter section.

Automatic switching section comprises resistors R1 to R3, preset VR1, transistors T1 and T2, zener ZD1, and diode D1. Resistor R1, along with preset VR1, works as a voltage divider. When voltage across the telephone lines is 48V DC, the voltage available at wiper of preset VR1 ranges from 0 to 32V (adjustable). The switching voltage of the circuit depends on zener breakdown voltage (here 24V) and switching voltage of the transistor T1 (0.7V). Thus, if we adjust preset VR1 to get over 24.7 volts, it will cause the zener

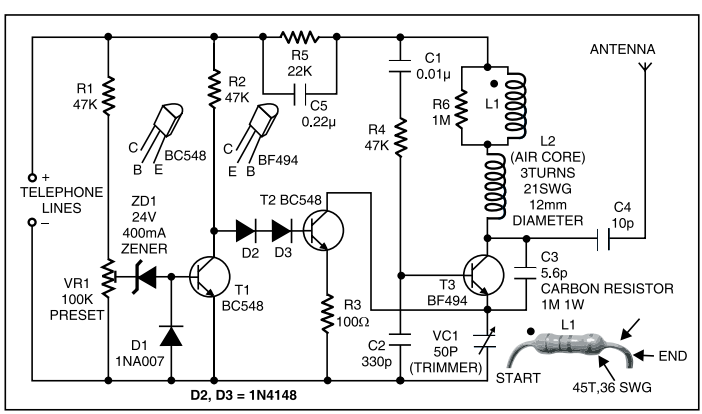


Fig. 4.14: Phone broadcaster

PARTS LIST		
T1, T2	- BC548	- npn transistor
T3	- BF494	- npn transistor
ZD1	- 24V, 400mA	- zener diode
D1	- 1N4007	- rectifier diode
D2, D3	- 1N4148	- switching diode
R1, R2, R4	- 47-kilo-ohm	- resistor, 0.25W
R3	- 100-ohm	- resistor, 0.25W
R5	- 22-kilo-ohm	- resistor, 0.25W
R6	- 1-meg-ohm	- resistor, 1W
VR1	- 100-kilo-ohm	- preset resistor
C1	- 0.01 µF	- ceramic disk capacitor
C2	- 330pF	- ceramic disk capacitor
C3	- 5.6pF	- ceramic disk capacitor
C4	- 10pF	- ceramic disk capacitor
C5	- 0.22µF	- ceramic disk capacitor
VC1	- 50pF	- capacitor trimmer
L1	- 45T, 36SWG	- Inductor (refer Fig)
L2	- 3T, 21SWG	- 12mm diameter air-core inductor
	- Antenna	- 13cm flexible insulated wire

to breakdown and transistor T1 to conduct. As a result, collector of transistor T1 will get pulled towards negative supply, to cut off transistor T2. At this stage, if you lift the handset of the telephone, the line voltage drops to about 11V and transistor T1 is cut off. As a result, transistor T2 gets forward biased through resistor R2, to provide a DC path for transistor T3 used in the following FM transmitter section (refer Fig. 4.14).

The low-power FM transmitter section comprises oscillator transistor T3, coil L1 and a few other components. Transistor T3 works as a common-emitter RF oscillator, with transistor T2 serving as an electronic on/off switch. The audio signal available across the telephone lines automatically modulates oscillator frequency via transistor T2 along with its series biasing resistor R3. The modulated RF signal is fed to the antenna. The telephone conversation can be heard on an FM receiver remotely when it is tuned to FM transmitter frequency.

Lab Note: While testing the circuit it was observed that the telephone used gave an engaged tone when dialled by any subscriber. Addition of resistor R5 and capacitor C5 was found necessary to rectify this fault.

Project 35
Anti-theft alarm

This circuit, using a 555 timer IC, can be used as an alarm system to prevent the theft of your luggage, burglars breaking into your house, etc. The alarm goes on when a hair-thin wire (36 to 44 SWG) is snapped/broken.

The circuit uses a 555 IC wired as an astable multivibrator to produce a tone with frequency of about 1 kHz to scare away the burglar. The circuit operates on a wide range of voltages, from 6V to 15V (refer Fig. 4.15).

The speaker and the circuit can be housed inside a small case, with holes drilled on the speaker side for the sound.

PARTS LIST		
IC1	- NE555	- timer
R1, R4	- 10-kilo-ohm	- resistor, 0.25W
R2	- 68-kilo-ohm	- resistor, 0.25W
R3	- 1-kilo-ohm	- resistor, 0.25W
C1, C2	- 0.01µF	- ceramic disk capacitor
C3	- 10µF, 25V	- electrolytic capacitor
LS1	- 8-ohm, 250mW	- miniature loudspeaker
Batt.	- 6V	- battery
	- 36 to 44 SWG	- copper wire

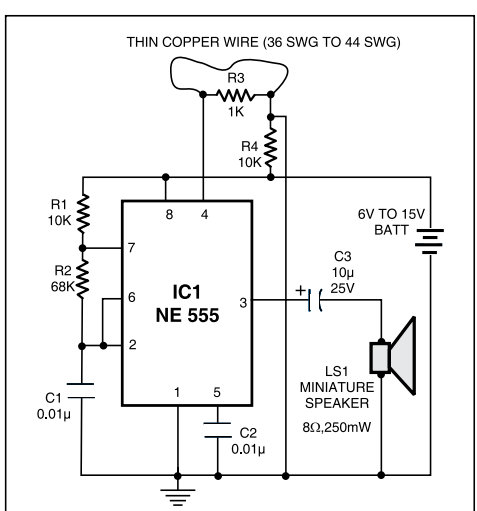


Fig. 4.15: Anti-theft alarm

Project 36
Touch dimmer

By simply touching this touch dimmer you can increase the light intensity of incandescent lamps in three steps. The touch dimmer is built around 8-pin CMOS IC TT8486A/TT6061A (manufactured by Tontek Design Technology for touch dimmer applications).

Initially, when mains switch is 'on', the bulb glows dimly. On second touch, the bulb gives medium light. At the third touch, the bulb is driven fully. The next touch puts off the light.

Since the IC is highly sensitive, use a long wire to connect the IC to the touch sensor. The circuit uses minimum external components. For touch plate, you can use a simple copper plate of 1cm×1cm or even the end of the lead wire.

Fig. 4.16 shows the touch dimmer circuit. Touch plate is coupled to the touch detector through 820pF, 1kV capacitors C1, C2 and C3 connected in series. Internally, IC TT6061A's touch signal is connected to the counter/decoder via a resistor, and clock input CK is connected to the counter/decoder via a frequency generator. Line frequency signal is taken through R4 at pin 2 of IC TT6061A. At zero crossing, the TRIAC1 (BT136) triggers to drive a 200W bulb. The 6.8V power supply is taken directly from mains through resistors R1 and R3, diode D3, capacitor C4 and zener diode, and fed to power-input pin 3 of IC1. Capacitors C1, C2 and C3 connected between touch input pin 4 and touch plate remove the shock potential from the touch plate, so do not replace these capacitors with a single capacitor or with a capacitor of a lower voltage rating. The circuit has 230V AC mains available in the circuit; therefore, **it is dangerous to touch the circuit when the mains switch is 'on'.**

PARTS LIST

IC1	- TT8486A/TT6061A	- dimmer pad IC
TRIAC1	- BT136	- triac
D1, D2	- 1N4148	- switching diode
D3	- 1N4007	- rectifier diode
ZD1	- 6.8V,0.5W	- zener
R1, R5	- 1-kilo-ohm	- resistor, 0.25W
R2	- 620-kilo-ohm	- resistor, 0.25W
R3	- 39-kilo-ohm	- resistor, 2W
R4	- 1.5-meg-ohm	- resistor, 0.25W
R6	- 6.8-meg-ohm	- resistor, 0.25W
R7	- 10-kilo-ohm	- resistor, 0.25W
C1, C2, C3	- 820pF, 1KV	- mica/polyester capacitor
C4	- 100µF, 25V	- electrolytic capacitor
C5	- 0.47µF, 25V	- electrolytic capacitor
C6	- 0.47µF	- polyester capacitor
S1	- SPST	- toggle switch
Bulb	- 60W, 230V	- bulb
Supply	- 230V AC mains	

Pin assignments of IC TT6061A

Pin No.	Pin Name	Function description
1	CK	System clock input
2	FI	50Hz line frequency
3	V_{DD}	Power input pin for V_{DD}
4	TI	Touch input
5	CI	Sensor control input
6	NC	Not connected
7	V_{SS}	Power input pin for V_{SS}
8	AT	Angle-trigger output

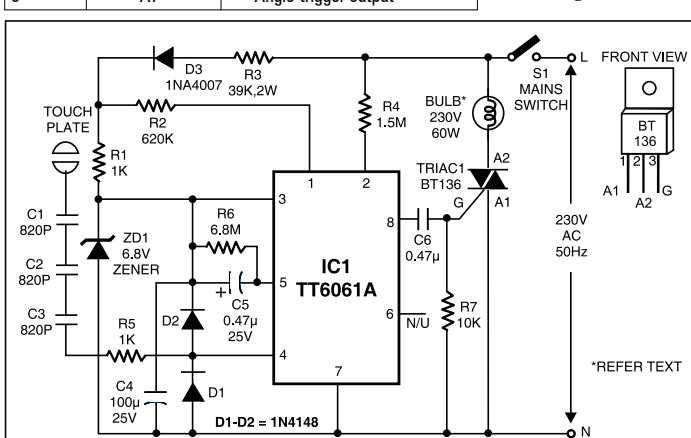


Fig. 4.16: Touch dimmer circuit

Project 37
Doorbell using UM3561

UM3561 (siren sound generator) is a low-cost, low-power CMOS chip designed for use in alarm and toy applications. The IC includes oscillator and selection circuitry, so a compact sound module can be constructed with only a few additional components. Pin configuration and mode selection (Table 4-1) are reproduced here.

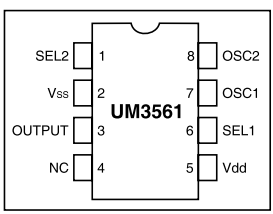


Fig. 4.17: Pin assignment of UM3561

Note: J1 jumper is to be shorted only for the machine gun sound (position 4).

Fig. 4.17 shows the pin assignment of UM3561 and Fig. 4.18 shows the circuit diagram of a doorbell. Transistor T1 is normally cut-off, as its base is pulled towards ground via resistors R1 and R3. When the doorbell switch is pressed, transistor T1 is forward biased via R2. The output across its emitter resistance R6 fires TRIAC1, causing LAMP1 to light. Simultaneously, zener ZD1 develops 3.1V to activate UM3561 siren sound generator. The sound produced will be as determined by the position of jumpers J1 and J2 in accordance with the mode selection truth table. The lighting of lamp and sounding of alarm will last for the duration the doorbell switch S1 remains pressed.

TABLE 4-1
Mode selection table

J1, J2 Position	SEL1	SEL2	Sound Effect
1	NC	NC	Police Siren
2	Vdd	NC	Fire Engine Siren
3	Vss	NC	Ambulance Siren
4	X	Vdd	Machine Gun

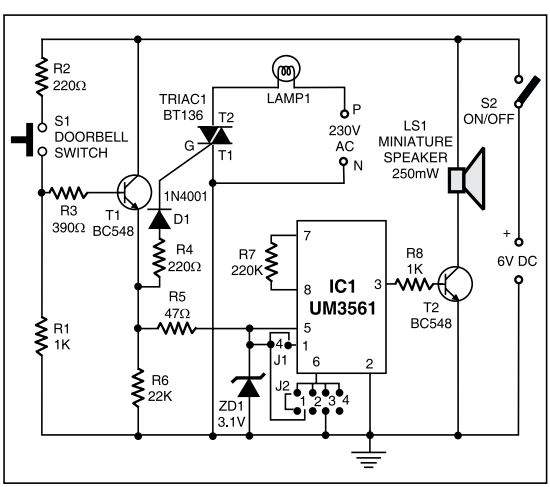


Fig. 4.18: Doorbell using UM3561

PARTS LIST

IC1	- UM3561	- siren sound generaor
T1, T2	- BC548	- npn transistor
TRIAC1	- BT136	- triac 4-amp.
D1	- 1N4001	- rectifier diode
ZD1	- 3.1V, 0.5W	- zener
R1, R8	- 1-kilo-ohm	- resistor, 0.25W
R2, R4	- 220-ohm	- resistor, 0.25W
R3	- 390-ohm	- resistor, 2W
R5	- 47-ohm	- resistor, 0.25W
R6	- 22-kilo-ohm	- resistor, 0.25W
R7	- 220-kilo-ohm	- resistor, 0.25W
LS1	- 8-ohm, 250mW	- miniature loudspeaker
S1	- push-to-on (SPST)	- tactile switch
S2	- SPST	- toggle switch
J1	- 2-pin (M) FRC	- connector with shorting jumper
J2	- 8-pin (M) DIP, FRC	- connector with shorting jumper
Lamp1	- 60W, 230V	- bulb
Supply 1	- 6V DC	- for circuit
Supply 2	- 230V AC mains	- for bulb

Project 38
Line-powered two-tone ringer

We sometimes need an extra telephone ringer in another room to alert a telephone subscriber of an incoming call. A low-cost, 2-tone ringer, IC LS1240, which is commonly used as part of a telephone circuit, can be wired externally to do the job as long as the telephone line is extended to the place where the extra ringer is to be installed.

A functional block diagram of LS1240 DIP-8 IC is shown in Fig. 4.21. It has an in-built bridge rectifier-cum-regulator circuit, which helps to save on the component cost. The complete circuit diagram for the external ringer, using IC LS1240 (manufactured by Bharat Electronics and ST Microelectronics, amongst others), is shown in Fig. 4.22.

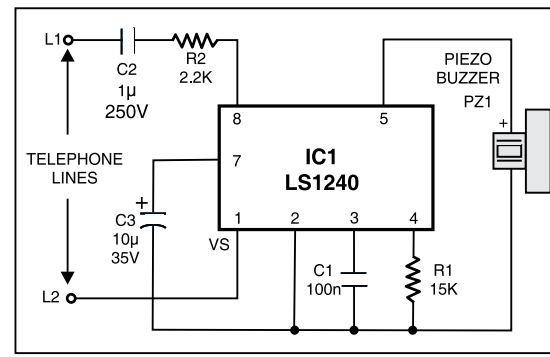


Fig. 4.22: Line-powered two-tone ringer

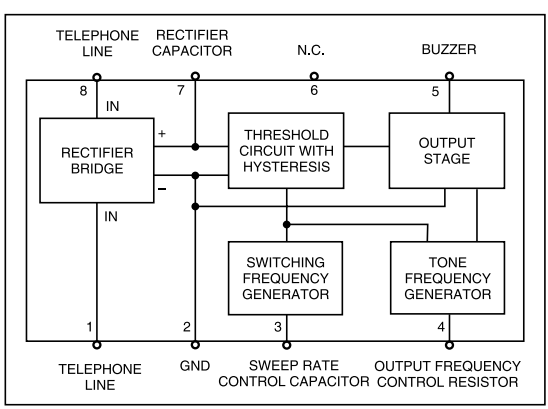


Fig. 4.21: Functional block diagram of LS1240/1240 A two-tone ringer

The supply voltage is obtained from the AC ring (80V AC RMS) signal and is regulated inside the IC itself so that noise on the line does not affect the correct operation of IC. The two tone frequencies generated are switched by an internal oscillator in a fast sequence, which appear at the output amplifier driving the piezo buzzer element directly. In case you want to replace the piezo buzzer with a loudspeaker, you may do so after adding a 0.1µF capacitor in series with pin 5 of IC1. Both tone frequencies (f1 and f2) and the switching/sweep frequency (f_{SWEEP}) can be externally adjusted. The value of R1 for a desired f1 frequency, and values of the other tone frequency f2 and sweep frequency f_{SWEEP}, can be found using the following relationships:

$$R1 = \frac{2.72\times10^4}{f1\ (Hz)}\ (1\text{-}0.04\ ln\ \frac{f1}{1943})$$

where abbreviation '*ln*' stands for natural logorithm

$$f2 = 0.725f1$$

$$f_{SWEEP} = \frac{750}{C1\ (nF)}$$

with the given value of components f1≈2 kHz, f2≈ 1.5 kHz and f_{SWEEP} ≈ 9.5 Hz.

PARTS LIST

IC1	- LS1240	- two-tone ringer
R1	- 15-kilo-ohm	- resistor 0.25W
R2	- 2.2-kilo-ohm	- resistor 0.25W
C1	- 100nF	- polyester capacitor
C2	- 1 µF, 250V	- bipolar paper/polyester capacitor
C3	- 10 µF, 35V	- electrolytic capacitor
PZ1	- piezoelectric buzzer	

Project 39
Ding-dong bell

This simple and cost-effective doorbell circuit is based on IC 8021-2. It is an 8-pin mask programmed ROM (read-only memory) IC, which is easily available. The IC is pre-programmed to produce 'ding-dong' sound each time its pin 3 is pulled low. The sound output from the IC has to be amplified for driving a loudspeaker, as its output is inadequate for directly driving the speaker.

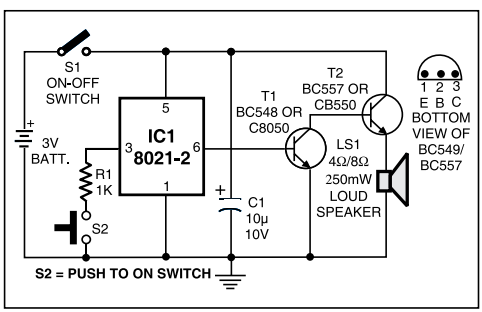


Fig. 4.23: Ding-dong bell circuit

PARTS LIST		
IC1	- 8021-2	- mask pre-programmed IC
T1	- BC548/C8050	- npn transistor
T2	- BC557/CB550	- pnp transistor
R1	- 1-kilo-ohm	- resistor, 0.25W
C1	- 10 µF, 10V	- electrolytic capacitor
LS1	- 4-ohm/8-ohm	- miniature loudspeaker 250mW
S1	- SPST	- toggle switch
S2	- Push-to-on	- tactile switch
Batt.	- 1.5Vx 2	- 3V supply

Therefore a complementary pair, two-transistor amplifier is used to amplify the audio output signal from the IC to produce a fair level of sound through the speaker.

During the standby period, the IC consumes nominal current of less than a milliampere. Thus, we can afford to keep switch S1 closed. Each time switch S2 is pressed, a double ding-dong sound is produced. If you try to press switch S2 a second time while the first ding-dong sound is still not over, it has no effect whatsoever.

Project 40
Rechargeable white LED torch

Rechargeable torches come with their own set of problems. You need to replace the bulbs and charge the batteries frequently. The average incandescent light-emitting diode (LED) based torch, for instance, consumes around 2 watts. Here's a rechargeable white LED-based torch that consumes just 300 mW and has 60 per cent longer service life than an average incandescent torch. Fig. 4.24 shows the circuit of the rechargeable white LED-based torch. The reactive impedance of capacitors C1 through C3 (rated for 250V AC) limits the current to the charger circuit. The resistor across the capacitors provides a discharge path for the capacitors after the battery is charged. The red LED1 indicates that the circuit is active for charging. The torch uses three NiMH rechargeable button cells, each of 1.2V, 225 mAH. A normal recharge will take at least 12 hours. Each full recharge will give a continuous operational time of approximately 2.5 hours. Recharge the battery to full capacity immediately after use to ensure its reliability and durability. The charging current is around 25 mA.

A voltage booster circuit is required for powering the white LEDs (LED2 through LED4). An inverter circuit is used to achieve voltage boosting. Winding details of the inverter transformer using an insulated ferrite toroidal core are given in the schematic. The number of 36SWG wire turns in the primary and secondary coils (NP and NS) are 30 and 3, respectively. If the inverter does not

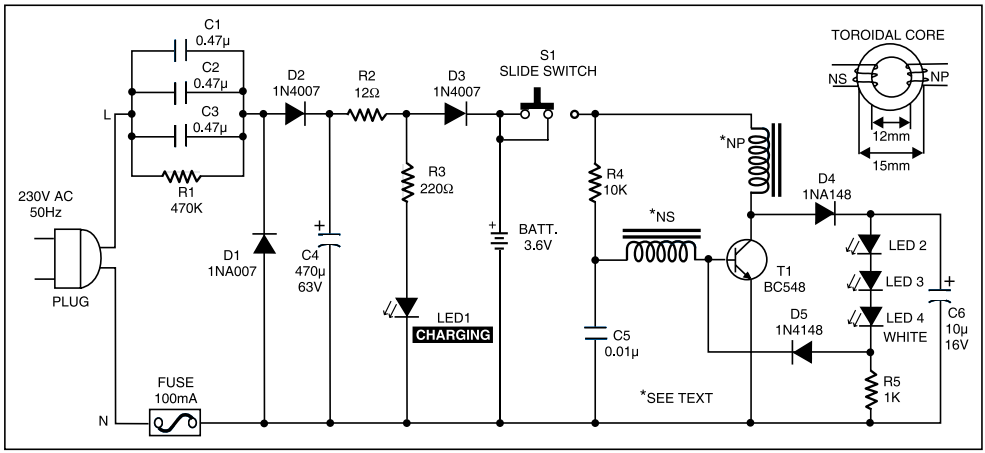
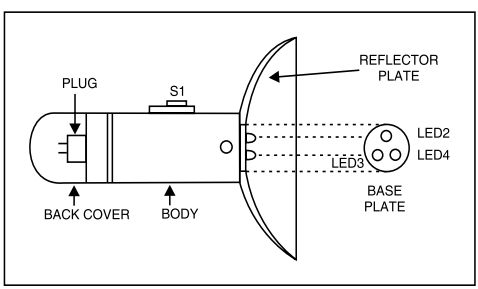


Fig. 4.24: Circuit of rechargeable white LED torch

PARTS LIST		
T1	- BC548	- npn transistor
D1, D2, D3	- 1N4007	- rectifier diode
D4, D5	- 1N4148	- switching diode
LED1	- 5mm, red	- LED
LED2-LED4	- 5mm, white	- LED
R1	- 470-kilo-ohm	- resistor, 0.25W
R2	- 12-ohm, 2W	- wire-wound resistor
R3	- 220-ohm	- resistor, 0.25W
R4	- 10-kilo-ohm	- resistor, 0.25W
R5	- 1-kilo-ohm	- resistor, 0.25W
C1, C2, C3	- 0.47µF	- capacitor paper/polyester, 250V AC rated
C4	- 470µF, 63V	- capacitor, electrolytic
C5	- 0.01µF	- capacitor, ceramic disk
C6	- 10µF, 16V	- capacitor, electrolytic
S1	- SPDT	- slide switch
Batt.	- 1.2Vx 3	- 3.6V rechargeable battery
Core (T-16)	- 16x9.5x6mm	- toroid ferrite core
Wire	- 36SWGx1m	- enamelled copper wire
Fuse	- 50mA	- cartridge type (with holder)

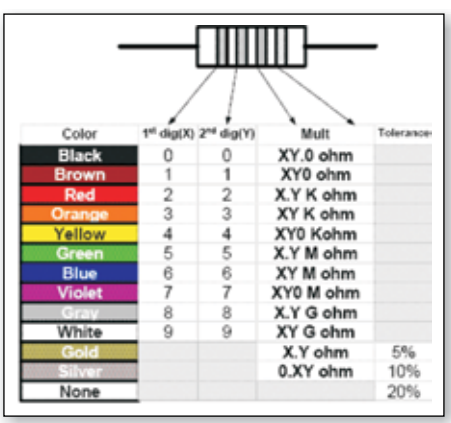


Fig, 4.25: Suggested enclosure for the white LED torch

oscillate, swap the polarity of either (but not both) the primary or the secondary winding. A reference voltage from resistor R5 provides a reflected biasing to the transistor and keeps the output constant and regulated. The suggested enclosure for the torch is shown in Fig. 4.25. ●

About the book

This book (Part 1, in particular) is aimed at budding hobbyists and freshers who desire to step into the fascinating world of electronics, but have little electronics' background. It will impart them necessary knowledge in electronics fundamentals, wiring/assembly of circuits on a breadboard/stripboard etc. and their testing. Even the experienced professionals, who have not kept themselves abreast with the changing technology, will also have something to gain from it. Part II of the book, provides complete details of over 40 interesting projects (from elementary to fairly advanced level), which have been duly tested by the EFY Lab. These projects have been picked up out of a list of nearly a thousand circuits that have appeared in EFY magazine over the past decade or so. Additional material has been added to aid understanding of the basic chips (ICs) used in these circuits, with a view to enable their proper assembly and testing.



Color	1st dig(X)	2nd dig(Y)	Mult	Tolerance
Black	0	0	XY.0 ohm	
Brown	1	1	XY0 ohm	
Red	2	2	X.Y K ohm	
Orange	3	3	XY K ohm	
Yellow	4	4	XY0 Kohm	
Green	5	5	X.Y M ohm	
Blue	6	6	XY M ohm	
Violet	7	7	XY0 M ohm	
Gray	8	8	X.Y G ohm	
White	9	9	XY G ohm	
Gold			X.Y ohm	5%
Silver			0.XY ohm	10%
None				20%

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